THE *Petroleum* Engineer — **Management Edition**

Exploration—Drilling—Producing • Refining—Petrochemical—Gas Processing • Oil and Gas Pipelining

AUGUST, 1955 • VOLUME XXVII • NUMBER 9

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The Petroleum Engineer, published monthly, August through June, semi-monthly in July, by The Petroleum Engineer Publishing Company, 800 Davis Building, Dallas 2, Texas. Subscription rate to the Petroleum Industry, United States and Foreign, $5.00 per year, $8.00 for two years; $1.00 for single copy. Entered as second-class mail matter May 1, 1932, at the post office in Dallas, Texas, under the act of March 3, 1879.

Gulf Waters Are Muddied Again

The waters of the Gulf of Mexico have been muddied again but not by an act of nature this time.

Controversy over whether the State of Louisiana or the Federal Government owns certain offshore areas has been much in the public eye of late. Vital question is where does the State's domain end and Federal jurisdiction begin? State officials assert the seaward boundary extends three leagues (10½ miles) from the coast. Federal officials claim it is three miles. There is a difference here of seven miles, but to further complicate matters there is also disagreement over what constitutes the coast line.

Louisiana points to a survey made by the Coast Guard in 1895, and adopted by the legislature, which places the coast line in some instances as far as 30 miles from the nearest dry shoreline. Apparently the survey marked off the area where water becomes too shallow for safe navigation, and in some areas water is only two feet deep although it may be several miles from dry land.

On the other hand the U. S. Interior Department declares Louisiana is entitled to submerged lands only to three geographical miles from the coast, and that the coast line is that established by the department in 1951, which is the point where land and water meet at low tide.

The disputed area is referred to as the "twilight zone" and in spots attains a width of 35 to 40 miles. It is thus seen that the area is a sizable one and involves a monetary value running into the millions.

Unable to reach an agreement, Federal and State officials in July both offered offshore leases to bidders, some 73,500 acres of which was in the "twilight zone." This placed bidders squarely in the middle, an uncomfortable place to be. Bids were submitted on the Federal leases, none on State leases. Louisiana has no escrow statute that would make it possible for bidders to recover their money if they later lost in court; the Federal government does.

Louisiana's attorney general stated prior to the lease sale that parties accepting leases "will do so at their peril." In the meantime the question of Louisiana's boundary is pending in the U. S. Supreme Court.

All this leaves successful bidders for offshore leases in a quandary as to just where they stand.

The necessity for agreement between State and Federal authorities is obvious, but the need is also immediate. The hurricane season ends in September when offshore activity could go ahead at a greatly accelerated pace. But the uncertainty arising from the present situation will continue to be a deterring factor until a solution is found.

FRANK H. LOVE.

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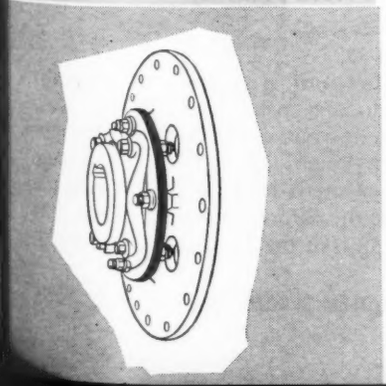

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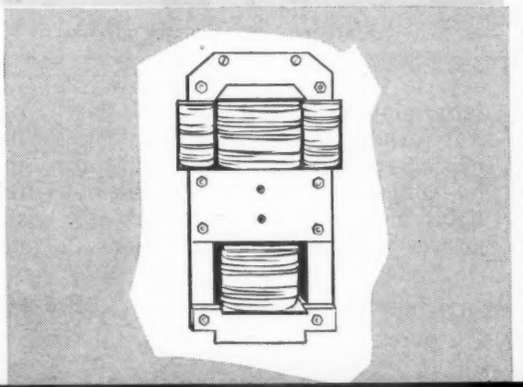
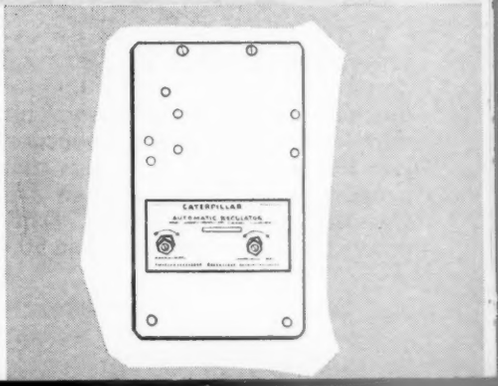


The control panel—adjustments locked at installation. No further attention required.



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HIGHLIGHTS ★ ★ ★

Digest of News and Comment

Oil cartel suit against 5 major oil companies should be ready for prosecution within the next year, according to Assistant Attorney General Barnes. The suit was filed in 1953 by Attorney General Brownell for conspiracy to control and split up world production and markets. Defendants named are Socony Mobil, Texaco, Gulf, Standard of California and Jersey Standard.

★ ★ ★

Government's fast tax write-off program has been labeled by Treasury Secretary Humphrey as "an artificial stimulus of a dangerous type," who has demanded a sharp cutback in the number of grants issued. While not opposed to the entire program, Humphrey suggests that its use be restricted to "very special cases where there is a present or pressing need for goods that would be a must in time of war."

★ ★ ★

Gulf Oil has moved into first place as producer of ethylene with the completion of its second plant at its Port Arthur, Texas, refinery. Designed to produce 220,000,000 lb of the petrochemical yearly, the unit will add about 10 per cent to the nation's ethylene output capacity. Feed stock for the new plant will be cracked refinery gases produced at the Port Arthur refinery.

★ ★ ★

"Drive More . . . it gets cheaper by the mile" campaign is being conducted by the Ethyl Corporation, designed to show dollars-and-cents advantages of greater car use. At the same time, the program, spearheaded by a national advertising campaign, stimulates demand for all automotive products and services. Ethyl claims that increasing average car mileage by 500 miles would increase gasoline sales by 1.2 billion gallons.

★ ★ ★

After three years of quiescence, Iranian oil has boomed back on the world market with daily production exceeding 300,000 bbl. This represents nearly half the production rate lost during the 3½ years that properties of Anglo-Iranian Oil Company were nationalized. Daily production last fall was less than 50,000 bbl when the Shah of Iran approved an agreement leading to the formation of an eight-company consortium. The group has promised that country that it would increase exports to 600,000 bbl daily by 1957.

★ ★ ★

Oil consumption in the U. S. is expected to rise above the 3-billion-barrel mark, according to forecasts of a 5 per cent increase over last year's 2.8-billion-barrel figure by the Independent Petroleum Association of America. Gasoline consumption during May and June jumped forward 8 per cent over last year, as did demand for heavy fuel oils. Diesel oil and asphalts, used in road building, is getting a big play to help make 1955 a bigger year.

★ ★ ★

Federal Gulf tidelands lease sale may net the government almost $110,000,000 in bonuses and first year rentals, final tabulations show. Of the total, over $100,000,000 was for 252,807 acres making up 94 tracts offsetting the State of Louisiana, and almost $8,400,000 for 27 tracts comprising 149,760 acres off Texas.

Oil questions get all the right answers in a new OIIC exhibit available to the industry for display at fairs, conventions and meetings. The 8-ft exhibit offers literature and photographic information on several oil subjects. Appeal is drawn by lights and color transparencies, to answer currently key oil questions.

Tulsa University has been given Stanolind Oil & Gas Company's former research laboratory center, valued at $950,000. Included in the gift are 23 acres of land, 29 brick and metal buildings, a chemical plant, reactor tower, and an experimental oil well. A group of Tulsa, Oklahoma, business executives has been assigned to study possible uses for the facilities.

★ ★ ★

Oil lease sale, Osage Indian style, has netted the Oklahoma tribe $2,390,900 in bonuses at one of the largest of the quarterly auctions ever staged. Site of the bidding for 391 tracts of 160 acres each was a tiny movie house which stayed packed with 500 oilmen for nearly 11 hours. The Osage Indians made money at a rate of $300,000 an hour on such bids as Phillips Petroleum's offer for one tract of $60,000.

★ ★ ★

Denver, Colorado, residents began using natural gas from state fields for the first time in history during July. Natural Gas Producers, subsidiary of Colorado Interstate Gas Company, brought 4,000,000 cu ft of gas on stream from the Continental Oil Company operated plant in the Little Beaver area through a Colorado Interstate line running from Hugoton, Kansas, to Denver.

★ ★ ★

Second quarter oil imports ran 15 per cent higher than the same 1954 period, the IPAA has reported. Importing company schedules filed with the Texas Railroad Commission indicate that imports for July, August, and September will average 1,105,000 bbl per day. Association added that reduced domestic production, averaging 6,555,000 bbl daily, plus increased refinery runs during June, has resulted in an improved crude stock position.

★ ★ ★

Natural gas bill to exempt producers from direct federal controls has passed the House by a narrow vote of 209 to 203. The measure represents a long hard-fought battle since the Supreme Court returned its decision in the Phillips case in 1953.

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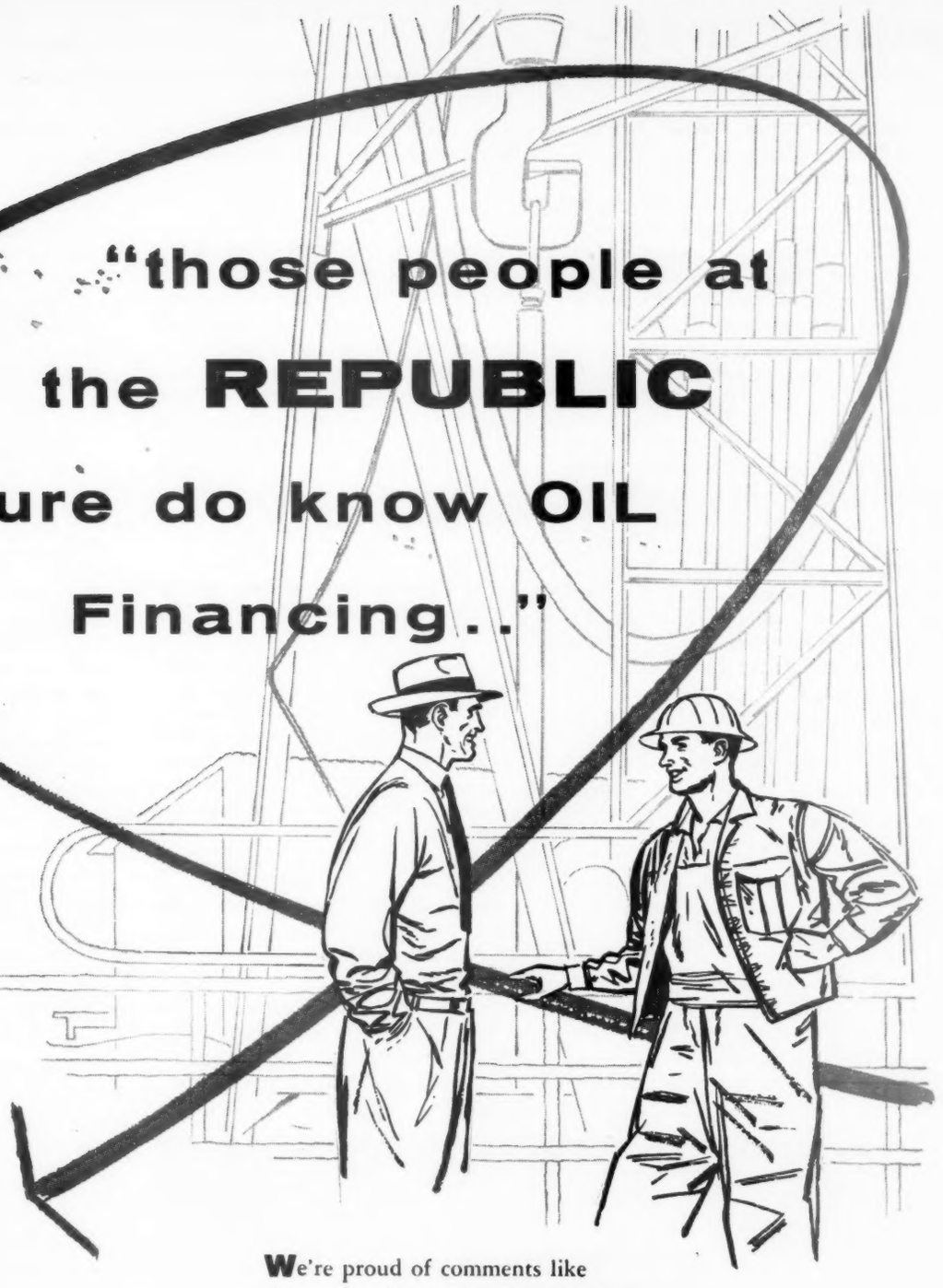

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Raw gas from Pacific Northwest Pipeline Corporation's gas line now under construction will provide charge stock for a new ammonia fertilizer plant in southeast Washington state. The plant, constructed by the Phillips Pacific Chemical Company, recently formed by Phillips Petroleum Company and Pacific Northwest, will produce 200 tons daily of anhydrous ammonia. Completion is expected late in 1956.

★ ★ ★

Appeal proceedings have been filed following a Seattle, Washington, trial in which a federal district court jury returned a $240,000 verdict in favor of a former gasoline jobber in a private antitrust case against 7 companies. George F. Moore, the operator, charged that the firms conspired to refuse him gasoline because of price-cutting policies. The jury found Moore to be damaged to the extent of $80,000, but under treble damage provisions of the Sherman Act, was awarded the larger amount.

★ ★ ★

Richfield Oil Corporation has entered an exciting exhibit in the new Disneyland playground in Anaheim, California. The company tells the story of oil vividly in a Walt Disney created CinemaScope cartoon entitled "The World Beneath Us," an 840 sq ft Diorama model of the Los Angeles Basin, and a working model of an underground reservoir complete with flowing wells and sub-surface storage facilities.

★ ★ ★

Foreign obligations have forced Secretary of State Dulles to drop a veil of secrecy around details of the international Iranian oil agreement. The five U. S. companies involved in the cartel are now subject of an investigation studying possible antitrust violation. Dulles said that the plan, as exists, does not violate such laws and that the agreement was fully justified to settle the Iranian crisis from 1951 to 1954.

★ ★ ★

Foreign oil flowed into the U. S. at an average daily rate of 1,126,000 bbl during the months of April, May and June, according to figures released by the IPAA. A lower level of imports may be expected during the months of July, August, and September. Importing companies told Texas Railroad Commission they had scheduled an average of 1,105,000 bbl per day.

★ ★ ★

Largest all-Canadian oil company, Canadian Oil Companies, Ltd., has entered negotiations to buy assets of Anglo-Canadian Oil Company Ltd. Board of Anglo-Canadian has recommended the sale and the offer will be brought before shareholders for approval soon.

Union Oil Company of California's $20,000,000 building project is now underway in Los Angeles. Completion will give Union the highest building in that city and provide a total of 1,000,000 sq ft of floor space for the company's home office and divisional personnel. Main building will rise 13 stories, including a three level parking garage underground, and four adjoining structures.

Capital expenditures for Sunray Mid-Continent for 1955 has been set at $50,000,000. This amount exceeds by $4,000,000 the combined expenditures of the Sunray Oil Corporation and Mid-Continent Petroleum Company prior to their merger. All phases of operations including producing, plants, pipe line and marketing will get a share of the allotment.

★ ★ ★

R. B. Anderson, former Assistant Secretary of Defense will be main speaker at the fourth annual convention of the Association of Desk and Derrick Clubs in session September 2 and 3. David A. Shepard, director of Jersey Standard and Admiral H. B. Miller, executive director of the Oil Industry Information Committee, will also speak at the New York City gathering. Keynote speech will come from Mrs. Irene Stimson Cox, secretary-treasurer and director of the Panhandle Producing Company and immediate past president of ADDC.

★ ★ ★

Wholesale gasoline prices on the Atlantic seaboard continue to drop by 3/10 to ½ cent per gallon. Esso Standard has adopted cutbacks initiated last month by Socony Mobil and Sinclair. Atlantic Refining has indicated it would join in the price revision.

★ ★ ★

Esso Research and Engineering Company has installed the world's most radioactive piece of material produced for peacetime use, at its Linden, New Jersey, radiation laboratory. The 13-in. section of cobalt pipe will be used in experiments, to find if atomic energy can be used to make gasoline, petrochemicals, and other oil products.

★ ★ ★

A second Rocky Mountain Oil Show, set for 1957, has been slated as a result of the success of the first, Casper, Wyoming, show in June. Oil field equipment valued at more than $10,000,000 was exhibited, drawing some 20,000 people.

★ ★ ★

Guatemala is preparing a final draft of a new oil law similar to those established recently in Venezuela and Turkey. Exploration concessions could reach 900,000 acres. On discovery of oil a company could apply for an exploitation right good for 40 years, and could be extended for an additional 20.

48 hours instead of 45 days!

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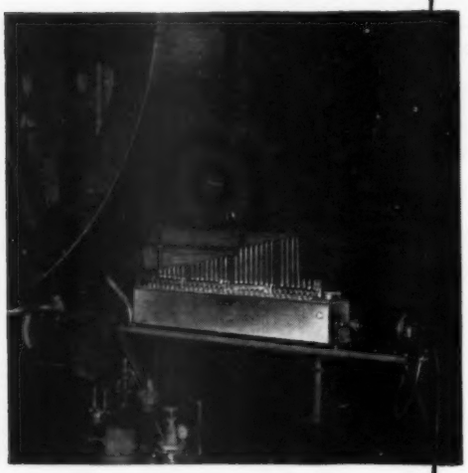

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Federal government made money disposing of 25 synthetic rubber plants (27 were up for sale). Plants were sold for $270,800,000. Building of the war-time plants cost taxpayers $128,000,000. Additional operating and non-operating expense ran $132,700,000, representing recovery of $10,000,000 more than the net cost.

★ ★ ★

D. D. Feldman Oil & Gas, Dallas, Texas, typical of independents making a play into foreign operations, has filed claims on areas in western Italy. The location is near Gulf Oil's Pescara discovery. Feldman is also negotiating for concessions in France, Sicily, Switzerland, and in the Middle East.

★ ★ ★

Opposition to industry-borrowed personnel in government appears settled with the writing in of duty restricting clauses into legislation extending the Defense Production Act. These WOC (without compensation) employees will be limited to advisory positions, eliminating the possibility of job duplication feared, especially in the Office of Oil and Gas.

★ ★ ★

Eight billion barrels of oil reserves in California, twice the present estimated total, is possible through the use of secondary recovery methods, Stanford University petroleum engineering professor Frank G. Miller told House subcommittee investigating oil on the Pacific Coast. Miller estimates that "upwards of 90 per cent of oil produced in California now is produced by 'depletion drive'." Similar testimony by others has lessened possibility of federal help for oil pipe line from Texas to California.

★ ★ ★

Fuels and lubricants for gas turbine engines will be a major subject at the Atlantic City meeting of the National Petroleum Association, September 14-16. Active research work is underway to develop the gas turbine engine for use in railroads, cars, and ships, with current leanings toward middle-of-the-barrel and residual fuels rather than gasolines for power.

★ ★ ★

Merger of Lion Oil Company and Monsanto Chemical Company will be submitted for stockholder approval September 23. Already cleared by the boards of directors, the agreement would permit the oil firm to operate as "Lion Oil Company, a division of Monsanto Chemical Company, with T. M. Martin as president of the Lion division.

CANADIAN OIL Settles Down to Steady Growth

There is more drilling and less exploration —refineries hit top of expansion program—increase of consumption drops slightly and predictions are that eastern Canada will continue to import at the same time oil is exported in the West—annual production remains only 4 per cent of reserves.

H. G. Cochrane

THE current trend in the Canadian petroleum industry for the first half of 1955 has been aptly described by J. R. White, Imperial Oil president, addressing the National Federation of Financial Analysts Societies in New York in May. He stated, "The growth of production and development in Western Canada is tapering off from the postwar skyrocket phase to a more rational rate of progress."

Weather conditions curtailed drilling operations this spring in Alberta and Manitoba, particularly in the new Pembina field, though drilling in Saskatchewan and British Columbia actually showed an increase over last year. At the end of May, 203 rigs were reported drilling. Completions for the first four months stood at 759 wells, compared with 615 for the same period of 1954.

Seismic crews in the field, which had reached a peak of 168 in 1954, were down to 118 parties in the spring, though considerable recovery was expected later.

Domestic industry sales up to early June were falling slightly short of the 10 per cent gain over 1954 predicted earlier, and industry marketing experts expect the average over the full year to be a little lower. Consumption of refined products, they say, will probably show an increase of 6 or 7 per cent over 1954, compared with the 4 and 5 per cent rise in U. S. consumption predicted by U. S. economists.

EXCLUSIVE

Production and Refining

Alberta nominations for June were at a record high of 319,350 bbl per day, compared with 278,000 for the same time last year, attaining an all-time record of over 336,000 bbl daily the second week of the month. Production at the end of May came from 5369 wells. The Transmountain pipe line, on which a throughput of 77,000 bbl had been expected for June, was already exceeding the throughput expected for the end of the year after the opening of the Anacortes refinery. Refineries in Alberta were taking 64,000 bbl per day, in Saskatchewan 41,000 and in Manitoba close to 15,000. Ontario, however, was taking less, probably due to increasing competition from products shipped westward out of Montreal via the Trans-Northern products pipe line.

Refineries are in the midst of a vast expansion program, which over 1954-1955 will add $185,000,000 worth of new refineries and modernization of older ones. Present capacities and current additions by regions are shown in the accompanying tabulation. In addition, a new wax plant, with a capacity of 35,000,000 lb of wax per year, will be built next year by Imperial Oil at Sarnia to produce a new type of petroleum wax, the first of its kind in the world. Extremely pliable, with high gloss and low melting point, it promises an improvement over waxes now used in treating arthritis.

Refining and production of Saskatchewan's medium and heavy crudes are enjoying an unprecedented boom. A new refinery at St. Paul, Minnesota, will be taking 20,000 bbl per day late this year. Small Saskatchewan refineries are accepting a larger proportion of heavy crude and are offering a visible market of 6200 bbl daily for Coleville crude. Its high asphalt qualities are being recognized.

Pipe Line Activity

Pipe line building is continuing actively, with contracts recently awarded for 331 miles of gas trunk line from Brock, Saskatchewan, via Biggar to Saskatoon and Prince Albert. Another contract for 106 miles of oil pipe line has been awarded from the Sturgeon Lake Oil field to Bickerdike Station on the Transmountain pipe line.

Another pipe line is projected to connect the Etzikom gas field in Southern Alberta with Medicine Hat for supplying gas to a $22,000,000 petrochemical plant being built by Northwest Nitro Chemicals, Ltd., for fertilizer manufacture, to be opened in the fall of 1956.

Discoveries

Several promising discoveries have already been made this year. One of these was at Clear Hills in the Peace

River area on a previously unproductive older geological horizon. At Joffre, east of Red Deer, Alberta, another sizable Viking Sand discovery was brought in, while at Sundre, 65 miles northeast of Calgary, an important new light crude source was uncovered in the Mississippian limestone.

At Carrot Creek, northeast of Edson, Alberta, high gravity oil was found in the D1 Devonian at 7700 ft, while at Smoky River in Northwestern Alberta gas was found in the Cadomin formation at 7600 ft. Indications of another pool of medium-light gravity oil were also shown in a Jurassic discovery at 3900 ft near Gull Lake, Saskatchewan, in May. Other important gas discoveries were made at Rimbey, Drumheller and Nevis, all in Alberta, and in Northeastern British Columbia. A June sale of Crown Reserves in the Pembina area brought the Alberta Government $27,300,000, with California Standard the largest purchaser.

Fifteen Per Cent Growth Yearly Foreseen

Addressing the Canadian Institute of Mining and Metallurgy meeting at Toronto in May, Fred G. Cottle, transportation manager, Imperial Oil, Ltd., predicted an increase of 25 per cent over the next 5 years in prairie oil consumption, to 154,000 bbl per day in 1960. For markets in Eastern Canada, he foresaw a 90 per cent increase to 246,000 bbl per day by 1960, while for the Pacific market he looked for an increase of 108 per cent to 173,000 bbl per day. These increases would add up to a consumption for western oil of 573,000 bbl daily by 1960, a 71 per cent increase over the present, or an average growth of 15 per cent annually over the next 5 years.

Cottle expressed the view that Canada's real marketing problem today was not that of finding an outlet for all the crude that can be produced efficiently in the West at any given time. It was, rather, to develop the largest available economic markets and provide pipe line facilities to reach them. "But the possibilities of western crude supplying the Montreal market," he said, "had been intensively studied, and the economic problems involved appear to outweigh by a large margin the apparent advantage to Canadian producers."

These views were in line with those of Imperial's President J. R. White, who in April forecast a steady enlargement of Canada's export market for oil, mostly on the Pacific Coast and in the Twin City area. He expressed the belief that Canadian crude would maintain its position in Pacific Coast markets.

Montreal Market Needed

A different opinion, however, was expressed by G. M. Furnival, vice president of Cal-Standard. Speaking before the annual meeting of the Engineering Institute of Canada in May, he expressed doubt that Canada would be allowed to export more than 100,000 bbl daily to the United States by 1960, or about twice the markets captured on a competitive basis to date.

This export, Furnival forecast, plus Canada's domestic consumption would in 5 years time only absorb about half of Canada's potential production, unless the Montreal market could be supplied from the West as well. Thus Montreal, with its expected 225,000 bbl per day consumption worth $250,000,000 yearly, was the answer to the problem facing producers in the Prairie Provinces.

Canadian crude, he continued, was presently supplying about half Ontario's consumption. Ontario's refining capacity over the past few years had expanded only 102 per cent, compared with a 224 per cent increase for the capacity in the Montreal area. If the Edmonton-Sarnia pipe were extended to Montreal, Redwater crude could almost compete there now with Venezuela crude.

Making allowances of 4 cents price differential for the difference in grade allowances of U.S.M.C. minus 40 per cent tanker rates, and of 3 cents per 100 bbl-miles pipe line tariff for the 2250 miles from Redwater to Montreal, 35-deg Redwater crude with the present field price of $2.49 could be delivered at Montreal for $3.243 per bbl. Compared with this, 32-deg Oficina crude from Venezuela, with its field price of $2.82, was being delivered in Montreal for $3.195, he pointed out. With Canadian currency at par with the U. S. dollar, Redwater oil would be competitive without further cuts in wellhead prices!

TABLE 1. Canadian refinery capacity by regions in barrels per day

Region	Operating	Under construction	Total
Maritime provinces	18,300	*41,625	41,925
Quebec	199,000	31,000	230,000
Ontario	150,000	7,950	157,950
Prairie Provinces	165,600	†225,650	187,050
British Columbia	56,000	2,000	58,000
Northwest Territories	1,250	—	11,250
Total	590,150	108,225 (Net 86,025)	676,175

* Includes 18,000 replacement Nova Scotia.
† includes 4200 replacement Manitoba.

. . . Canadian consumption will increase at average rate of 15 per cent for the next 5 years is prediction . . .

The advantages of extending the Edmonton-Sarnia pipe line to serve Montreal were tremendous, he emphasized. This would raise Canadian production for 1960 to within 80 per cent of potential. It would save for Canada over the 5-year period some $1,500,000,000 now paid out to foreign countries, diverting this huge sum into Canadian exploration and development. It would add a further $150,000,000 to provincial revenues and enrich Canada's Federal treasury by a further $150,000,000 in taxes, duties, etc.

Obstacles for Producers

It is not to be denied that the rapid expansion of Canada's oil industry has brought with it many problems for the producer. Recoverable reserves and potential production have grown far faster than available markets, bringing about severe proration. Excluding the huge Pembina field, reserves have grown at an average of 370,000,000 bbl per year over the past 7 years, or 320,000,000 bbl per year net after production.

It is estimated some 4000 additional Pembina wells will be drilled over the next 5 years, adding a further 400—450,000,000 bbl per year to the present reserves, now estimated at 2,900,000,000 bbl. In 1954 Canada's annual production was only 4 per cent of total reserves, compared with approximately 8 per cent for the United States.

Today practically every quarter section has been committed under lease or reserve, and parcels are constantly changing hands, with an increasing amount of acreage reverting to the Crown. It is becoming increasingly difficult to assemble a block of acreage sufficiently extensive to justify risking the cost of a wildcat well.

Taxation regulations present another problem. Canada's depletion allowance credits for exploration and development do not apply until the whole costs have been recovered and the company is earning a net profit. To obtain the benefit of depletion allowance, it is necessary to abandon or curtail further exploration and confine attention to developing properties already acquired. Thus the very thing

the depletion allowance is intended to encourage is not accomplished. This compares unfavorably with the United States method of calculating depletion allowances on gross revenue.

The typical Canadian oil operator shows a tax revenue 3½ times the net profit figure. As Gerald Godsoe, executive vice president of British American Oil, told shareholders at his company's annual meeting recently, "Governments are too eager to tax at the gas pump or elsewhere. This could set in motion complex reactions detrimental to the industry and the entire economy."

Some Incentives Too

Nevertheless, there are other aspects which help to tip the odds in favor of the explorer. Statistics released by the Canadian Petroleum Association covering the period 1948-54 show that while odds in Canada are not as favorable as in the United States for a wildcat discovering a 1,000,000 bbl field, they are better in Canada for finding a 10,000,000-bbl pool and much better for finding a 50,000,000-bbl pool!

Also on the favorable side was the revision to the Canadian Bank Act last year, which gave banks the power to facilitate loans to the oil industry and to simplify the method of taking security. And last year Alberta initiated the offering of drilling reservations under which joint venture agreements may be made for drilling, thus enabling companies to spread the risk on their wildcats. Another incentive to exploration was offered by Saskatchewan last year, in the form of a call for cash bonus bids on large parcels of land. There is a good market for natural gas in the western half of that province, and a large block of acreage to the east of it is almost virgin territory.

Gas Line Projects Still Await Approvals

The West Coast Transmission pipe line from Peace River and northern British Columbia now has Transport Commission approval, as well as full authority from Alberta for export. It is now awaiting a federal export license which in turn awaits passage of new modified legislation at Ottawa, all of which should make the project more acceptable to the U. S. Federal Power Commission.

The size of line now planned is 30 in. in place of the 24 in. originally projected. It will supply 250,000,000 cu ft per day toward the 350,000,000 ft per-day market in Canada and the U. S. A. Completion is planned to Vancouver late in 1956 and to the U. S. Pacific states in 1957.

Following Trans Canada Pipeline Company's double failure late in April to carry out their financing or to obtain help from the Canadian Government in the form of acceptable guarantees, all hopes for a possible start on construction this year of even a portion of the line between Alberta and Winnipeg, were abandoned. However, the Transport Board at Ottawa granted the company an extension of time for financing to October 28.

Trans Canada has since concentrated its efforts on the purchase of the Montreal gas manufacturing and sales division of Hydro-Quebec, at a cost of some $30,000,000. They have also asked for U. S. Federal Power Commission approval for importing a further supply of Texas gas from the Tennessee Gas Transmission Company's system and plan to extend their 24-in. pipe 370 miles from Toronto to Montreal to build up the Montreal market. This market is estimated to be capable of taking 30,000,000,000 cu ft per year in 5 years time, compared with the present 8,000,000,000 ft per year consumption of manufactured gas in that city.

Completion of the purchase of Montreal distribution system from Hydro-Quebec is contingent on proof of Trans Canada's ability to furnish an adequate supply of gas. This can only come through FPC approval of Tennessee Gas Transmission's proposal to export a greatly stepped-up flow of gas into Ontario.

New Contract With Winnipeg

Meantime, Trans Canada made a deal in May with the Winnipeg and Central Gas Company to supply Winnipeg with 200,000,000,000 cu ft of gas on a 20-year contract, worth to them $50,000,000 and possibly $75,000,000. This, their first and most important contract since the original contract with Northern Natural Gas for supplying the Minneapolis area, signed more than a year ago, failed to get FPC approval and will have to be renegotiated.

But Alberta gas may be available in Winnipeg for building up the market long before Trans Canada gets its line built by way of the 10-in. Canadian Hydro-Carbons, Ltd., products pipe line via Edmonton, Regina, Brandon and Minnedosa. The idea is that the Hydro-Carbons Company would switch back to the transport of petroleum products when the Trans Canada pipe line reached Winnipeg.

Idea of Interchange Revived

At the end of May Tennessee Gas Transmission made Trans Canada an offer to purchase up to a half a billion cu ft of Alberta gas per day at 95 per cent load factor to be delivered through a 34-in. pipe line at a price of 25 cents per 1000 or possibly more at Emerson, on the Manitoba-Minnestota boundary, thus assuring producers a considerably better wellhead price than they were offered a year ago.

. . . Marketing of natural gas has hit many snags — principle of Canadian-U. S. interchange may smooth way . . .

This is the major element in an alternative proposal, now being considered by the Canadian Cabinet at Ottawa, for a vast interchange arrangement, whereby Tennessee Gas Transmission would build a line from Emerson through Minneapolis to tie in with their own north-south trunk line at Mercer, Pennsylvania, for augmenting their supply to the New England states. Meantime Tennessee Gas Transmission would be building up the Montreal market via the proposed pipe line through Toronto, as well as making many smaller Ontario cities gas-conscious en route. Such a plan would eliminate, or at least delay the costly pipe line link from Winnipeg and Toronto north of Lake Superior, which has been the major stumbling block in Trans Canada financing.

Will 'Canada First' Policy Be Modified?

Thus a major shift in Canada's policy which has stubbornly adhered to the "all-Canadian" concept may be in the making. It would involve some form of agreement between the two countries to insure continuance of supply even during times of national emergency in either country. Since it would also require the blessing of the slow moving U. S. Federal Power Commission, the early flashing of a green light can hardly be expected.

Other proposals competitive to Trans Canada have been made, however, for building an all-Canadian pipe line since Trans Canada announced its inability to finance last April. If Ottawa elects to adhere to the principle of the all-Canadian line, the whole question would again be tied up until Trans Canada's time extension runs out on October 28.

But the principle of broad interchange of natural gas between Canada and the United States has long been advocated by producers, economists, and provincial governments, as it would benefit both countries. The feeling that recognition of this principle was in sight was evident at the Canadian Gas Association Convention at Niagara Falls, Ontario, early in June, the keynote of which was "Natural Gas on the March." * * *

Oil and gas operations create tax problems all their own—An expert here outlines some sp

Federal Taxation of *OIL* and *GAS*

Leland E. Fiske

THE oil and gas industry is one of varied activities. In this complicated industry, ranging from the exploration for oil and gas to the marketing of its products, many special tax problems have arisen, some of which are peculiar to the industry. This article will deal principally with these special problems. The statements made are for the most part based upon provisions of the Internal Revenue Code of 1939 which were not changed by the Internal Revenue Code of 1954. To the extent that they are based upon new provisions of the 1954 Code, concerning which regulations have not yet been issued, it should be understood that the conclusions reached may need to be modified after regulations are issued. Subjects, the discussion of which are based at least in part upon new provisions of the 1954 Code, include the property, depreciation, operating losses, partnerships and corporations.

Exploration for Gas and Oil

Exploration for oil and gas is carried out by a study of the underground formations to detect and map buried structures favorable for the accumulation of oil and gas. The several methods used in making these studies are called geological and geophysical methods. All costs of geological and geophysical surveys which result in the acquisition or retention of oil and gas properties must be capitalized as a part of the cost of the properties. If no properties are acquired or retained, the cost of the survey may be charged off as a loss when completed. A survey made solely to locate a well to be drilled may be treated as part of the development cost of the well. The cost of scouting, leasing, and similar activities of the land department may be deducted as a current expense.

Acquisition of Oil and Gas Properties

Ownership of oil and gas in place does not depend on legal title, but upon the ownership of an economic interest. An economic interest is owned if the holder is entitled to a share in the proceeds from the sale of the oil and gas and must look solely to the oil and gas for a return of his investment. The investment is returned through depletion allowances. Types of economic interests, subject to depletion, are leases, mineral interests, royalties, overriding royalties, oil payments and net profits interests.

The customary method of developing an oil and gas property is through an oil and gas lease, permitting the operator to enter and drill for oil. A bonus is usually paid which is a capital cost to the operator and income subject to depletion to the landowner. Annual rentals, paid prior to drilling, are deductible by the operator and ordinary income to the landowner. If the property produces oil, the landowner receives a royalty, which is excluded from the operator's gross income and included in the landowner's income, subject to depletion. Shooting leases are often taken giving the operator the right to prospect a large tract and then select a part by paying an additional bonus. Both the original and subsequent bonuses are a capital cost to the operator, of the lease selected, and income subject to depletion by the landowner.

Bonuses may be payable in installments. In some cases the landowner has sold the right to receive these payments and claimed capital gain. Despite adverse court decisions, the Internal Revenue Service continues to treat the proceeds as ordinary income subject to depletion.

If prospective oil and gas land is acquired in fee, the price must be reasonably divided between surface and minerals. If a well is drilled the operator becomes an operating owner. When oil and gas rights are sold, prior to leasing, a sale of minerals has been made subject to capital gain. If the property is under lease or the sale is of a nonparticipating royalty, the purchaser gets only a right to a royalty.

A lease owner may transfer the lease and retain an overriding royalty. If the overriding royalty does not run for the full life of the lease, it is an oil payment. While usually expressed in dollars, an oil payment may also be expressed in barrels or in time, and may be carved out of a royalty or a larger oil payment. A net profits interest is an overriding royalty measured by profits rather than by production. Any of the above interests may be acquired by purchase instead of by retention.

If oil or gas properties are acquired in payment for services, their value is to be included in income. But two individuals may form a partnership, one contributing money to acquire properties, and the other services. Also, if materials or services are contributed in connection with the acquisition and development of oil and gas properties, in exchange for an economic interest in the properties, no income results but the costs incurred, if any, are capitalized.

When a producing property is purchased the cost must be reasonably divided between leasehold and equipment. If, because the property is nearing abondonment, or a large oil payment is retained by the seller, the purchase price does not exceed the value of the equipment, part of the cost must still be assigned to the leasehold. When the retained oil payment is from such a large fraction that the operator's income is not enough to pay operating expenses, the excess of operating and development expense during the payout period must be capitalized.

Development of Properties

An election is given to oil and gas operators to charge the so-called intangible costs of drilling wells and preparing them for production to expense, or to capitalize them to be returned through depletion. Where capitalization is elected there is a separate election for dry holes. Nearly all operators elect to charge drilling costs to expense. These costs include all costs incurred in drilling the well and preparing it for production except the cost of the actual materials placed in the well which are of a character having a salvage value, such as the casing, even though cemented.

Most wells are drilled by drilling contractors. Costs are charged to development expense when they become due to the contractor. If drilling is at contractor's risk this is at the completion of the well. If the contractor furnishes both drilling and equipment on a turnkey basis a reasonable divis-

*The views expressed are those of the author and do not necessarily represent the official position of the Internal Revenue Service.

EXCLUSIVE

ion of the costs must be made. Drilling costs paid in advance are deducted when the drilling is done. An operator on the cash basis deducts incurred drilling costs when paid even if payment is made with borrowed funds.

The election to charge drilling costs to expense does not apply to expenditures incurred after the well is completed, to take care of the production, such as pumping and storage facilities. If a well is drilled for a part of the working interest in a lease, only that part of the drilling costs allocable to the part acquired can be expensed; the balance is capitalized. If the interest is not a working interest, the full cost is capitalized. If drilling is done for cash and a working interest, the drilling costs are divided; those applicable to the working interest are development expense; the rest are applied against the cash, resulting in drilling income if less, or in cost of property, if more.

When a driller drills for a half interest but has a right to all working interest income until he recoups his costs, he may charge off the full drilling costs; but one-half of his remaining equipment cost will be transferred to leasehold costs at the end of the payout. Drilling contractors may elect to report income on either the cash basis, the accrual basis, or the completed contract basis.

Contributions made by an operator to a neighbor toward a well to be drilled by the neighbor, known as bottom hole or dry hole payments, are to be capitalized on the leases benefitted if the well is a producer, or deducted as a loss if the well is dry. The cost of drilling water wells for a water supply for drilling oil and gas wells, or as input wells for water flooding, may be charged to development expense. But a water well drilled for a water supply to operate the property or one drilled to dispose of salt water must be capitalized to be returned through depreciation.

Operation of Properties

In order to comply with the rules for computing depletion it is necesary to divide income and deductions in connection with the operation of oil and gas wells by properties. A property is each separate interest in oil and gas deposit on each tract. Properties may be separated geographically or by conveyancing, each oil and gas lease granted on a large tract resulting in a new property. But if contiguous leases with the same lessor are acquired in one instrument, they become one property; properties touching only at a corner are not contiguous. If several interests are acquired in a tract at different times, each interest is a separate property. Also each separate oil or gas producing horizon on each property is a separate property unless the operator elects to combine them.

The operator may elect to aggregate any two or more working interest properties in the same field whether or not contiguous, which may be conveniently operated as an operating unit. But one aggregation may be made in one operating unit, but subsequently developed properties may be added in the year of first exploration and development. The election is binding on subsequent years and properties not aggregated remain separate. A separate election is given to aggregate non-operated properties, such as royalties and oil payments, in contiguous tracts, upon a showing of undue hardship.

Gross income from the property is the amount for which the oil or gas is sold at the well; or if transported or refined prior to sale, it is the value at the well. There are excluded all royalties paid including net profits payments and gas well rentals in lieu of royalties. There is also excluded for computing 27½ per cent of gross income, but not for computing net income or the 50 per cent limitation, a proportionate part of the lease bonus paid, in the ratio of current production to expected total production.

Deductions applicable to the property for the purpose of computing net income before depletion include operating expense, development expense, overhead expense, depreciation, taxes, and losses. The overhead expense to be used is a reasonable part of the general expenses of the operator which do not apply to a particular department. These general expenses are first allocated to operating departments in proportion to direct expenses. The amount allocated to the production department is then further allocated to properties on a reasonable basis, usually in proportion to production. Losses to be considered are damages, and losses on sales of material. Miscellaneous lease earnings are a credit to operating expense, but gain on sale of an entire lease or its equipment is excluded from lease income.

Depreciation of Equipment

Operators may claim depreciation on equipment on oil and gas properties by one of several methods. The most common method is the straight line method, by which the cost less salvage is spread in equal annual amounts over the useful life. The unit of production method may be used for equipment on producing leases. By this method the cost less salvage is spread over the estimated total oil or gas production in proportion to each year's production.

The declining balance method may be adopted. By this method a constant rate of not over 200 per cent of the applicable straight line rate is applied each year to the remaining undepreciated cost, and no separate salvage need be provided. The sum of the year's digits method can best be explained by an illustration, taking an asset with a life of 5 years. When 1 plus 2 plus 3 plus 4 plus 5 are added, the result is 15. Depreciation for the first year will be 5/15 of the cost less salvage, the second year 4/15, and so on.

Drilling tools, less salvage, may be depreciated on the basis of days of use or footage drilled each year compared to the total expected days of use or footage to be drilled before the rig is worn out.

An operator may change from the declining balance method to the straight line method at any time. Any other change in depreciation method requires permission from the Commissioner of Internal Revenue. Depreciation may be computed by items, or by groups of items at a composite rate. All of the depreciation methods listed may be applied to group or composite accounts except the sum of the year's digits method, which can only be applied to items.

If depreciation is computed on the

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Following his graduation from the University of Kansas in 1916 with the degree of BS in mining engineering, he worked for 10 years as a geologist and petroleum production engineer for various oil companies, interrupted by one year's service in the U. S. Army Air Service during World War I. For the last 30 years his work has been in oil and gas taxation. During that time he has served as head of the tax department of a large oil company, has been in public practice as a consulting oil and gas valuation engineer, and for the past 15 years has been Chief Oil and Gas Engineer for the Dallas Region of the Internal Revenue Service, comprising the states of Texas, Oklahoma, Arkansas, Louisiana, and New Mexico. Fiske is a certified public accountant and a lawyer.

basis of average lives, no loss is allowable for retirements. The full cost of the equipment, less salvage recovered, is charged to the reserve for depreciation. It is the policy of the Internal Revenue Service to make changes in depreciation only when there is a clear and convincing basis for the change. For suggested lives of oil and gas equipment reference is made to Bulletin F issued by the Treasury Department.

Depletion of Properties

Depletion is allowable on economic interests in oil and gas properties, either a mineral fee, a lease, a lease bonus, a landowner's royalty, an overriding royalty, an oil payment, or a net profits interest, in the year the oil or gas is sold; for an operator reporting on the cash basis it is allowable in the year payment is received. Depletion is allowable computed on cost or on a percentage of income, whichever is greater each year.

Cost depletion is computed by dividing the cost of the oil and gas property by the estimated recoverable barrels of oil or 1000 cu ft of gas, to obtain a unit; and then by multiplying the current year's production by this unit. A new estimate of recoverable oil or gas is made in any year in which it is determined that the original estimate was wrong. Cost depletion on a bonus is computed by spreading the property cost ratably over the bonus and expected royalties, expressed in dollars. If future royalties can not be estimated only percentage depletion is allowed. Cost depletion for oil payments expressed in dollars, and for net profits payments, is computed by making an estimate of total recovery in dollars.

Percentage depletion for oil and gas is allowable at 27½ per cent of gross income from the property, not to exceed 50 per cent of net income before depletion. If cost depletion is greater than percentage, it is allowed in lieu of percentage depletion. The cost basis of the property is reduced each year by the depletion allowed, whether on cost or percentage, but not below zero.

When an oil and gas lease expires without production, depletion previously allowed on the lease bonus must be restored to income by the landowner in the year of expiration.

Other Operating Problems

If, due to litigation, the oil and gas income from a property is impounded, the income will be reported when the funds are released. Operating expense and depreciation will be currently deductible but depletion will be allowable at the time the oil and gas income is collected.

The owner of a lease may transfer it to another operator under an agreement whereby the second operator will develop the property and receive all income until his costs have been recovered, after which each operator will own a one-half working interest and share income and expense equally. This is known as a carried interest arrangement. Notwithstanding some conflicting court decisions, the Internal Revenue Service holds that during the payout period the carrying operator reports all income, and takes all deductions. At the time of the payout one-half of his remaining equipment cost becomes lease cost. The carried operator reports no income until he begins to receive it at the end of the payout period, and he has no investment in the well or the equipment.

In the interest of conservation and orderly development many oil and gas fields are being unitized. A unitization results in a non-taxable exchange of like property, a full interest in one or more leases being exchanged for a fractional interest in the unit. It is customary to exchange leases for leases on the basis of estimated oil and gas reserves; to exchange wells for wells on a footage basis; and equipment for equipment on an inventory basis.

If cash is paid to equalize the wells or the equipment, it represents additional cost to the operators making the payment and is boot on an exchange to the operators receiving the money. This money is taxable as capital gain to the extent of the gain realized, not to exceed the money received, if the properties have been held over six months; otherwise it is taxed as ordinary income. If the differences are adjusted by increasing or decreasing the size of the interests in the unit or by oil payments, no gain or loss results, such adjustments merely serving to increase or decrease the fractional leasehold interest held in the unit, by each operator.

The operation of distillate fields or oil fields with high gas-oil ratios requires the construction of a cycling plant or a gasoline plant to treat the wet gas. A cycling plant removes the propane, butane, gasoline and distillate and returns the dry gas to the ground, to maintain reservoir pressure and to store the gas for later recovery. A gasoline plant recovers the products and makes the dry gas ready for sale.

The operation of both cycling and gasoline plants involves manufacturing or refining; hence depletion is limited to the value of the wet gas at the mouth of the well. If wet gas is sold in the area to plants operated by others, these sales will establish the market value of the gas for computing depletion. If there are no sales of outside gas, then the value of the gas may be established by deducting from the product sales, the operating expense of the plant, depreciation on the plant, and a reasonable earning on the plant investment, usually 10 per cent per year. The remainder will represent the value of the wet gas, subject to depletion.

In recent years extensive offshore drilling has been undertaken, sometimes from permanent platforms, and more recently from sea-going barges. In general, the same rules can be applied to these offshore operations as to those located on shore, although the lives of equipment may be different in this type of service. If the well is located offshore and the flow tanks are onshore, the cost of transporting the oil from the well to the tanks, either in barges or by pipe line, must be excluded from the selling price in computing depletion, since depletion is limited to the value of the oil at the well.

Disposition of Properties

The basis of oil and gas properties for computing gain or loss, depletion and depreciation is usually the cost; but in some cases it is the value at date of acquisition; in others it is the cost to the preceding owner. The holding period ordinarily begins on the date the title is acquired, but for a lease, where title does not pass until a well is completed, it may begin when the contract has been signed to acquire the lease, and the operator moves in and starts to drill.

If a working interest has been held over six months and is sold for more than its cost, capital gain results; if held for less than six months, the gain is ordinary income. If the sale is at a loss it is an ordinary loss, if it exceeds gains from other similar properties. If an oil payment is retained, the cost must be divided between the interest sold and the interest retained on relative values. Sales of mineral interests and royalties also result in capital gain.

The sale of an oil payment carved out of a working interest, a royalty or a larger oil payment, is held by the Internal Revenue Service to result in ordinary income, subject to depletion, despite some recent adverse court decisions. But if the sale of the oil payment divests the seller of all interest in the property, capital gain is allowed. Thus A, owning an oil lease, may sell the working interest to B, retaining an oil payment; and then sell the oil payment to C. A has divested himself of the entire lease and gets capital gain on both sales. A might also sell part of his retained oil payment for its full life and get capital gain, as this would not be a carved out interest.

Dealers in oil and gas properties, who acquire them to sell to buyers, hold them as stock in trade, and all sales result in ordinary income. An in-

dividual who discovers oil on a property may sell it and have his surtax on the sale limited to 30 per cent of the selling price. This provision will be applicable to properties held less than six months; after the lease has been held longer the capital gain provision will be found more advantageous.

When an operator transfers a lease and retains an overriding royalty or a net profits interest for the life of the property he has made a sub-lease. Any cash he receives is applied first to reduce his equipment cost; the balance is a bonus subject to depletion. If the equipment cost exceeds the cash, the excess becomes a cost of the retained royalty.

If an oil property is conveyed as a gift, the transferor pays a gift tax and the recipient uses the same basis for depletion, depreciation and gain as the property had in the hands of the donor. The basis for determining loss, however, is the donor's basis or the fair market value of the property at the time of the gift, whichever is less. Gains on sales of equipment, which has been in use, give rise to capital gain; but sales of equipment which has never been used, such as warehouse stock, results in ordinary income. The granting of an easement for a pipe line right of way does not result in income; the proceeds are applied to reduce the cost of the land. But payments received for allowing geophysical shooting on land, if not a lease bonus, are ordinary income.

When an oil property is abondoned or destroyed due to a casualty the remaining cost, less any salvage recovered, may be deducted as a loss. When undeveloped oil and gas leases expire or are surrendered because of nonpayment of rentals, the cost may be deducted. The cost of non-producing royalties may be charged off as a loss in the year in which a dry hole drilled on or near the tract reasonably proves them worthless, even though title is still held; or an abondonment loss will be allowed in the year the royalty is quitclaimed to the predecessor in title, without consideration, if not previously condemned by drilling.

Net Operating Losses

If an oil and gas operator has an operating loss, it may be carried back two years and forward five years to reduce taxable income. Prior to 1954 it was necessary to reduce the loss by the excess of percentage depletion over cost depletion, both in the year of the loss and the years to which it was carried. Starting in 1954 this adjustment is not required.

If an individual has losses from a trade or business of more than $50,000 for five years, losses in excess of that amount are disallowed. In computing these losses development expenses on oil and gas wells are not included.

Partnerships and Associations

While a partnership is not taxed, each partner including his share of the net income on his individual return, the partnership is recognized as an accounting entity and reports all income, takes all deductions, and makes all elections. A partner may deal with his partnership as an individual and have gain on the transaction, just as though he were not a partner. If one partner contributes cash to a partnership and the other partner contributes an oil and gas property, the basis of the property in the hands of the partnership is the same as that of the contributor; also, this amount becomes the cost of the contributing partner's interest in the partnership. Under the general rule depletion, depreciation and gain or loss on the contributed oil property will be divided between the partners in the same proportion as gains and losses are shared; however, the partners may agree to divide these items so as to take account of the difference between the tax basis of the property and its value. An agreement among the partners to share other items of income and expense in a different proportion than their gains and losses will also be recognized in most cases. If the partnership is dissolved and the assets distributed in kind, no gain or loss results, but the cost of each partner's partnership interest becomes the cost of the assets received, to be allocated to properties.

If a group of owners of an oil and gas property appoints one of its number to operate the property, sell the products, pay the expenses and distribute the earnings, the group will be treated as an association taxable as a corporation, and be required to file a corporation return. This result can be avoided by limiting the authority of the operator to the operation of the property and the payment of the expenses; reserving to each owner the right to take his share of the oil and gas and sell it himself. Such a group may also elect not to be a partnership.

Corporations

If an individual owns an oil and gas property upon which he has discovered oil and which has been developed with borrowed funds, he may have a very valuable property the cost basis of which is less than the indebtedness against it, due to a small original cost and the charging of development costs to expense. If the individual then forms a corporation and exchanges the oil and gas property for the corporation's stock, the excess of the debt assumed by the corporation over the cost basis of the property will be taxed at the time of the transfer, as capital gain if held over six months, otherwise as ordinary income.

When a corporation distributes oil and gas properties as an ordinary dividend to its shareholders who are not other corporations, the fair market value of the property on the date distributed, subject to the exclusions provided by law, is included in income, and becomes the stockholder's basis for subsequent depletion, depreciation and gain or loss.

If the shareholder is another corporation, the amount included in income and in basis is the fair market value of the property or its cost basis in the hands of the distributing corporation, whichever is the lesser. If a corporation distributes oil and gas properties in complete liquidation of its stock, capital gain or loss is ordinarily recognized to the stockholders measured by the difference between the cost basis of the stock and the fair market value of the property at date of distribution, and such fair market value becomes their basis of the properties received. But if a corporate shareholder owns 80 per cent or more of the stock of the distributing corporation, no gain or loss is recognized and the basis of the property is the same as in the hands of the distributing corporation. However, if the corporate stockholder acquired at least 80 per cent of the distributing corporation's stock by purchase during a period of not over 12 months and the distributing corporation is liquidated completely within two years, then the basis of the properties is the adjusted cost basis of the stock. * * *

YOU PAY TAXES ON YOUR METHODS

The taxation of oil and gas is a complex subject, but one which directly affects every oil and gas operator. It is possible to carry out transactions by different methods, which while arriving at the same end, may result in widely different tax consequences. For this reason the oil and gas operator needs either to be familiar with the tax laws or to have competent tax counsel.

XUM

Russian writer tells of effort to get petroleum industry to use automatic machines in statistical and accounting work—officials criticized for making poor use of "electro-integrators"

USSR Struggles With Electronic Computers

ALTHOUGH much has been already done in the direction of simplifying the organization and reducing staffs on the administrative and accounting side of the Soviet petroleum industry and in simplifying also the recording and statistical work, yet much more remains to be done. A writer, N. F. Bryzgalin, in the May issue of the oil industry journal (*Neftyan. Khoz.* pp 12-15), says that only the first step has been taken, and suggests various ways in which more mechanization, the greater use of computers, etc., could be speeded up.

A vast amount of statistical work is still done by slow and cumbersome methods, very liable to error. For example, in preparing a statement of oil yields per 100 wells for only one month requires: (1) 36,300 entries in 8 different formulations; (2) 30,100 calculations; (3) 1700 divisions and classifications; in all, 68,100 operations. It is admitted that many of these are probably quite unnecessary, and that a more rational system could be adopted, especially by more mechanization.

During the past four years many oil undertakings connected with the Ministry of the Petroleum Industry, USSR, have had available a large number of electrical calculating machines and automatic tabulators. In all the principal oil regions mechanical accounting stations (MSS) and offices (MBS) have been established. Among the data to be dealt with of course are: Oil production, drilling footage, drilling tool life, labor and material expenditure.

In addition, many other items are listed, such as calculations required in research, in new projects and development work, in comparative costs of transport, capital expenditure in petroleum products, etc.

Requirements of the different officials, organizations, trusts, ministries, involved in the rather complex structure of the industry, and the special features of trading, both home and foreign under Soviet rule, mean a lot of extra statistical and accountancy work. One can only regard as special features certain items that are by no means clear in the original: Calculation of returns or estimates from housing and lodging surveyors (kvartiro-s' emshchik) and one or two others of like uncertain meaning.

One thing, however, is made quite clear and that is, in most of the oil undertakings where MSS and MSB have been set up, there is hitherto little appreciation of the new mechanized methods, and the extent to which they are used is most unsatisfactory.

The writer says that, in the Soviet oil industry, the most laborious work by present methods is in the compilation of returns of oil yields. In August of 1954 a plan for mechanizing operational and production data was introduced into three undertakings of the Grozneft combine. Experience thus gained has shown that it is fully possible to mechanize all such data compilation, and the labor required is reduced to at least one-fifth. High grade workers—geologists, economists, etc. —have thus been released for more important productive employment. It is found that the more mechanized accountancy can be centralized, up to a point, the more efficient it is.

The new methods applied to oil recovery permit the use of analytical computers or the like for supplying data for important research work.

Another valuable application is in connection with drilling tool life, to which the Soviet Oil Ministry has given increasing attention in recent years. Many special research institutes make a systematic study of drilling rig performance and supply relevant collated information to principles in the oil industry; but unfortunately these data are often much delayed and their praccal value reduced. It is emphasised that in many "drilling offices" little attention is given to this matter of drill efficiency, largely because statistical study is very laborious under present methods.

Research organizations, as well as drilling offices, are severely criticized for their indifference; although many of them are said to be fairly well equipped with the requisite machines, little use is made of them. At best they only use the calculating or adding machines (Russian arithmometers) in special cases.

By way of example—the VNIGNI (probably one of the research institutes in the oil industry) has lately been engaged in elaborate calculations relating to diffusion of gases. For one calculation only, of partial pressure in some locality or of the effect of gas yield from a given shelf or stratum, three or four of the laboratory staff might be engaged for a whole week. At the same time another organization, the VNII (initials of the tool research institute, but may possibly mean something else here), in dealing with similar calculations based on a much larger number of initial data, has used electro-integrators (Russian terminology) that completed the task in 15 to 20 minutes, or about 500 times as quickly.

Others to be criticized include some of the official bodies responsible for constructional work in the oil industry. Thus the Glavnefteproekt (oil-planning board) is said to have at least 16 invoicing and other machines, but makes poor use of them. These machines, combining both calculating and recording functions, can print estimates in 6 copies and perform various summating and other operations. Labor efficiency and output in this case are said to be tripled—a fairly modest multiple compared with most comparisons of the kind. But, adds the author, despite their manifold advantages, the planning departments of the Ministry prefer the old laborious time-wasting system. Some other similar examples are given. * * *

Translation by W. G. Cass, London, England.

EXCLUSIVE

Exploration, Drilling, Producing

Offshore Land for Douglas

Douglas Oil Company has been awarded a 320-acre parcel of municipal tidelands off Huntington Beach by the California State Lands Commission. Royalties paid to the state will be based on a sliding scale from 16⅔ to 75 per cent, depending on production development. Douglas is now preparing to drill a 5000 ft dual zone test to the Jones and Main zones from an on-shore location.

★ ★ ★

Penn Crude Price Up

Prices of Pennsylvania crude have been increased by the Joseph Seep Purchasing agency of the South Penn Oil Company. An across-the-board 10-cent barrel hike was recorded. This shoves prices in the Bradford districts (Bradford and National Transit) to $3.60, Middle district (National Transit) grade oil to $3.47, and Pennsylvania grade oil (Eureka Pipe Line Company) to $3.07. Simultaneous increases were posted by Ashland Oil & refining Company for Zanesville Pennsylvania grade crude, upping price per barrel to $2.82.

★ ★ ★

B-A Sets Records

British-American Oil Producing Company has announced net crude oil production of 25,300 bbl per day during May, to set up new records in crude oil and natural gas production during the first six months of 1955. B-A's U. S. subsidiary has completed 35 oil wells and six gas wells, with new discoveries in Texas, Nebraska and Colorado.

★ ★ ★

Johnston-Texam Merger

Proposed merger of the Johnston Oil and Gas Company and the Texam Oil and Gas Company, both of Houston, Texas, will be carried to stockholders August 24. A new company, result of the union, would be known as the Texas National Petroleum Company.

★ ★ ★

Texas Slates Sale

Texas School Land Board has scheduled another sale of oil and gas leases on public lands, including Gulf of Mexico tract, for September 6. Texas requires one-sixth royalty, $15 minimum bonus and $3 an acre annual rental. Requests for leases, prior to such sales, were open up until July 19; offerings, in turn, are announced this month.

East Texas Pressure Up

Increase in reservoir pressures in the East Texas field, as a result of waterflooding, has been recorded for the month of June. The 5.44 psi increase as reported by the Texas Railroad Commission was the result of water injection averaging 421,050 bbl daily for the month of June, down 3936 bbl from May.

★ ★ ★

Seaboard Joins Offices

Seaboard Oil Company is consolidating its Los Angeles and Bakersfield California, offices to be located in Bakersfield. The move will involve the geological, exploratory, land, engineering and accounting offices now in Los Angeles and the geological and land offices already situated in Bakersfield.

★ ★ ★

API Gives Cement Data

First official publication pertaining to oil field materials specifications, in distinction to equipment, has been released by the API division of production. "Specifications for Oil Wells Cements" is the result of four years of committee work in developing a recommended practice for testing cements, and establishes three regular, three retarded, and five sulfate-resistant classes of cement. Physical and chemical requirements are prescribed for each class. Testing procedure is covered under a separate publication, API RP 10B, and governs the sampling and testing provision of the new publication, Standard 10A.

★ ★ ★

Humble Revamps Work

Humble Oil and Refining Company has dissolved its gas division of the production department. Operation of all gas systems and gas plants will now become functions of the various production departments. A new gas engineering division has been set up to handle work formerly done by the engineering section of the former gas division. A new gas and gas products department has also been established.

★ ★ ★

Bishop Opens Offices

Bishop Oil company has opened new district offices at Abilene, Texas, and Denver, Colorado. Its office in Midland is being closed. The Denver office will promote district geological work, while the Abilene office will handle area production.

Reservoir Study Offered

Latest and complex phases of engineering involved in analyzing and predicting petroleum reservoir behavior will be presented in a graduate course at the University of Texas August 26 through September 15. The course is in cooperation with the Southern Regional Education Board, and academic credit will be given by Texas A and M College, Louisiana State University, Oklahoma A and M College and the Universities of Oklahoma and Tulsa. Shell Oil Company's chief reservoir engineer A. F. Van Everdingen will be a lecturer in the course, together with others on the University of Texas faculty.

★ ★ ★

AAPG Nominates Officers

Nominations for the 1956 slate of officers of the American Association of Petroleum Geologists have been announced. Two are candidates for president. They are Carey Croneis of Rice Institute, Houston, Texas, and Theodore A. Link of Link, Downing, and Cooke, Ltd., Toronto, Canada. Nominees for vice president are Ben H. Parker of Frontier Refining Company, Denver, Colorado, and Walter H. Spears of Union Producing Company, Shreveport, Louisiana. Other nominees include William A. Waldschmidt, consultant, Midland, Texas, for secretary-treasurer, and W. C. Krumbein of Northwestern University, Evanston, Illinois, for editor. Additional nominations may be made for any office until November 15 on receipt of a petition bearing the signatures of 50 or more AAPG members, 1955 President G. M. Knebel has announced.

★ ★ ★

Philippine Exploration

Standard-Vacuum Oil Company has been given approval by the Philippine Government to go ahead on a proposed method of settling problems arising from overlapping applications for exploration rights in Northeast Luzon. Under the settlement the Cagayan Valley would be divided into three sections with the Philippine Oil Development Company receiving concessions on two-thirds and Stanvac on one-third of the area, with cross-option provisions. Based on this formula and the anticipated granting of all other areas now under application, Stanvac is looking toward eventually exploring 900,000 acres in the Philippines.

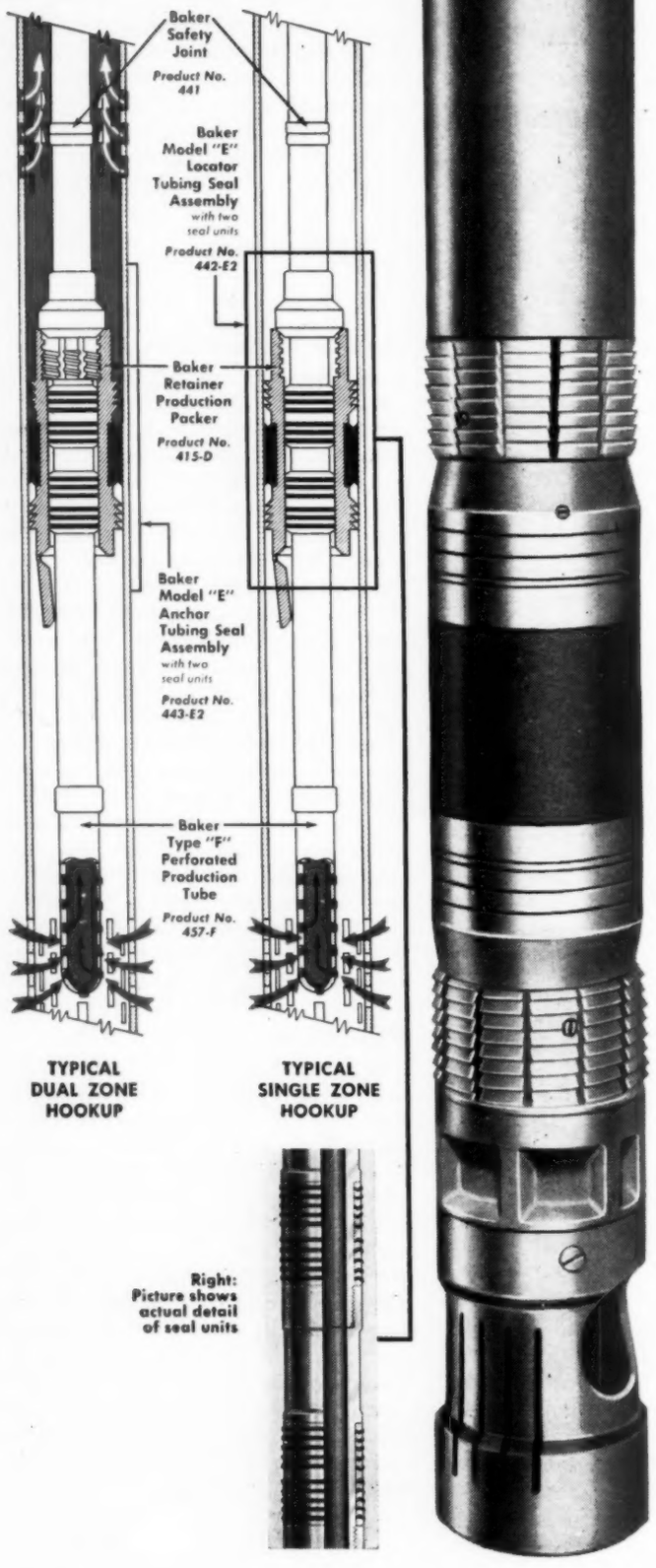
XUM

Single Zone

Dual Zone PRODUCTION

WITH 1 BAKER

RETAINER PRODUCTION PACKER


Baker Safety Joint
Product No. 441
Baker Model "E" Locator Tubing Seal Assembly with two seal units
Product No. 442-E2
Baker Retainer Production Packer
Product No. 415-D
Baker Model "E" Anchor Tubing Seal Assembly with two seal units
Product No. 443-E2
Baker Type "F" Perforated Production Tube
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TYPICAL DUAL ZONE HOOKUP
TYPICAL SINGLE ZONE HOOKUP

Right: Picture shows actual detail of seal units

Do you know that with only ONE Baker Retainer Production Packer you can equip your well for *either* SINGLE ZONE or DUAL ZONE production? And that you can accomplish *any* type of completion for *any* method of production to meet *fixed* or *changing* well conditions?

A single Baker Retainer Production Packer will also outperform many specialized tools when used as a TESTING PACKER – SQUEEZE PACKER – GAS LIFT PACKER – PERMANENT COMPLETION PACKER – WATER FLOOD PACKER – GAS INJECTION PACKER – CORROSION CONTROL PACKER – TUBING ANCHOR – ONE-WAY BRIDGE PLUG – PERMANENT BRIDGE PLUG.

Every production man should be familiar with the many operating advantages of this "Universal Type" Packer, which include . . .

WIRE LINE SETTING—The packer can be set with *wire line speed and accuracy,* using the same set-up just used for perforating. The Baker Packer also can be set on drill pipe or tubing.

SETTING UNDER HIGH PRESSURE—By using a lubricator, the Baker Retainer Production Packer can be set under high pressure. From the moment it is set, the self-contained, flapper-type, back-pressure valve closes and isolates pressure below the packer.

TUBING STRING IS ALWAYS "FREE"—That valuable string of tubing—whether 1,000 feet or 16,000 feet in length—can be removed by simply picking up the tubing weight.

EXCESSIVE "SET-DOWN" WEIGHT OR TENSION NOT REQUIRED—Even when squeezing, formation fracturing, or producing at any depth under pressure, a perfect pack-off is maintained independent of excessive set-down weight, or tension.

HOLDS PRESSURE DIFFERENTIALS FROM ABOVE OR BELOW—Two sets of opposed slips, and a resilient packing confined by lead and metallic sealing rings, effect a permanent pack-off that will hold any pressure differential *either from above or below the packer* that is safe for the well equipment.

Part 1

For the first time, a simplification of the various factors to consider when investigating water injection possibilities

Elements of Water Injection

J. Randolph Buck

WATER injection basically is the process of introducing water into an oil-bearing formation for the purpose of displacing oil into producing wells. If injection takes place before the initial reservoir pressure has been essentially depleted, the term "pressure maintenance" is applicable. In current usage, pressure maintenance is a normal technique, the results of which are classed as "primary" recovery. If, however, injection of water is delayed until after depletion of the reservoir or abandonment, the term "secondary" recovery becomes appropriate. This series will be more closely identified with secondary recovery although it is recognized that the same considerations generally apply to pressure maintenance operations in primary recovery. It is of interest to note that most producers in a position to choose between pressure maintenance or delayed secondary recovery usually can readily demonstrate that the former is preferable from both the technical and economic points of view.

It can be anticipated that within a relatively few years flooding of carbonate reservoirs will achieve a popularity equivalent to that now enjoyed by many of the sandstones today. To be included with the limestones and dolomites among the neglected orphans of flooding are those depleted fields too deep for current economic consideration or too small for conventional development.

For the above reasons, the attempt to specify at any given time what does or does not constitute an acceptable flooding prospect is limited by available knowledge, the concensus of past experience, and the judgment of the operator as to what degree of risk is acceptable. To overcome with managerial ability and technical ingenuity what was an obstacle of yesterday is an advancement for today. What appear to be restrictions today may present no problem tomorrow. Water injection has come a long way in the building of its present stature, yet there is ample room for further progress. Those who can learn from history and keep abreast of present developments will be in excellent position to participate in the rewards that are bound to be realized in the growth of this segment of the industry.

It is the purpose here (1) to point out the more important considerations and problems that should be analyzed in flooding projects, (2) to present personal, concensus, and difference of opinion as to current thinking with regard to the solution of these problems, and (3) to clarify the relationship that exists between the flood project as a whole and the numerous aspects of which it is constituted.

Geological Factors in Property Selection

Structure

No attempt will be made to define a floodable structure either as to depth, age, or type. Water injection programs are either now in operation or being planned anywhere from a few hundred feet to some 12,000 ft in depth. The entire range is wide open for investigation. Flooding received its start in fields of the Paleozoic (old life) era. This trend has been followed in the floods of the Eastern interior and Mid-continent areas but does not preclude consideration of the younger formations for which ample evidence indicates their favorable susceptibility to water by injection and by natural water drive.

In the case of deep fields, structure, stratigraphy, and the locations of existing wells are the most important features for initial consideration. An adverse situation in these catagories can quickly rule out the reservoir as a flooding prospect.

Faulting

Faulting should receive close attention. If the faults are sealed and radial in position, fault blocks or segments may be isolated and suitable for injection and subsequent control. Strike faulting can completely destroy the effectiveness of an injection program, particularly if the faulting occurs in a progressive en-echelon fashion updip. This type of faulting can be suspected in fields that for some unaccountable reason failed to develop the water drive apparent in neighboring fields producing from the same formation.

Shallow Fields

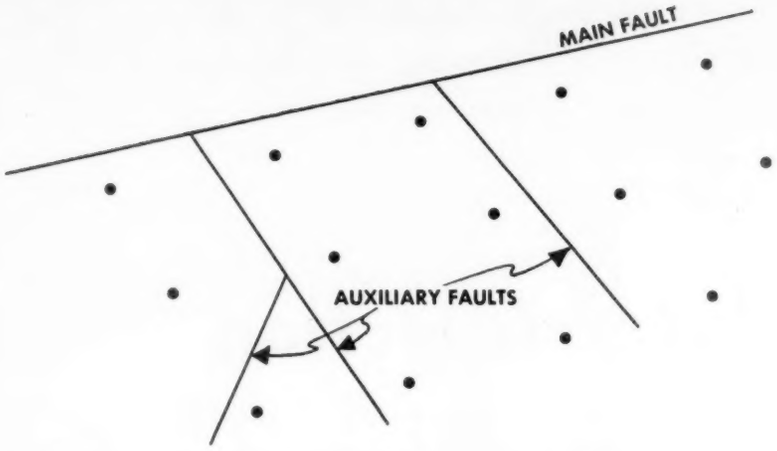
Shallow structures, 300-400 ft in depth, should be examined carefully since they cannot tolerate high injection pressures without rupturing the formation or possibly opening fracture planes extending to the surface. This latter hazard is especially real in areas of rough topography.

Relief

The productive relief is of interest for reasons other than the determination of injection well locations and

EXCLUSIVE

Editor's Note: This is the first of a series to give management, independent producers, superintendents, and operating engineers practical information on many of the important aspects of water injection. Material to be presented in future issues will include: Specific factors to be considered in the selection of flood properties; application of various flood patterns; unitization; well completions; water treatment; operational notes and procedures; recoveries and general flooding economics. Each article of this series has been scheduled in accordance with the logical approach to the problem "to flood or not to flood."



Field development map showing fault blocks which may be flooded separately.

overall flooding pattern. In Gulf Coast fields, where connate water values can be relatively high and where the oil zone is underlain by water, lack of adequate structural relief may place the entire oil sand in the so-called "transition zone" of higher than normal formation water saturation. On the other extreme, high relief and a steeply dipping formation may suggest that primary production was aided by gravity drainage, in which case waterflooding may not be expected to yield significant additional oil.

Sandstone

Where the pay is sandstone, it should have good porosity, good permeabilty and be continuous.

Porosity

Porosity is not itself a controlling factor in determining floodability, but is important since it relates to the oil in place. High porosity is no assurance of high recovery. It is entirely possible that a lower porosity sand could yield more oil because of more favorable characteristics among those that do control the water displacement process. In general, the lower the porosity, the superior must be the other flood factors to achieve the same recovery per unit of sand thickness.

Permeability

Permeability must be considered as a specific problem of the individual field. High permeability is necessary, however, in only the deep or the very shallow fields. In the case of the deep fields, high permeability is essential in order that sufficient water can be injected in relatively few wells at wide well spacings to maintain high liquid levels in producing wells, thereby minimizing lifting costs at such depths.

High permeability in shallow fields is mandatory so that water in commercially satisfactory quantities can be introduced into the sand at the necessarily low injection pressures previously mentioned. In all cases, the distribution of permeability should fall in a narrow range for best flooding results. It is far better for the permeability to vary from 20 to 200 millidarcys than from 20 to 2000.

In a non-uniform sand evidenced by the wider range, channeling of water through the highly permeable sections from the input well to the producer prevents the economic recovery of oil from the tighter zones. Where the permeability range is narrow, the formation of a uniform oil-water front, regular over the sand thickness, becomes a realistic probability. By conventional methods, flooding low permeability sands requires either higher injection pressures or closer well spacing. Experimentation has shown that for low permeability sands, higher injection pressures required tend to give more effective recovery for the same total water input. When one considers that the famous Bradford sand may have a permeability of but 10 millidarcys, it is apparent that high permeability is not in itself a prerequisite to successful flooding at average depths.

Directional Permeability

Permeability frequently exhibits directional characteristics. When permeability is higher in, say, the east-west direction than in the north-south, this fact should be recognized, if at all possible, since the knowledge aids in the selection or location of producing and injection wells. These permeability trends can often be detected from well pressure and production records. It is considered favorable if permeability in the horizontal direction exceeds that in the vertical. Effect of this factor is to keep fluids moving horizontally toward the producing well rather than always seeking an easier path into the more permeable sections. Continuation of this process leads to premature and uncontrollable breakthrough of water into the producer. Presence of a few shale streaks within the sand body similarly tends to break up the unwanted cross-flow of fluids.

Lensing

Permeability must be continuous at least from the injection well to the affected producers. Where wells are interspersed in a pattern arrangement, some lenticularity of the sand from the overall field point of view not only can be tolerated but might even be helpful in disrupting any tendency for water to channel over great distances. Where injection wells are located only around the flanks of a field, the sand members must be continuously permeable throughout. Lensing of the sand would result in failure of the project.

Texture

There is no agreement at the present time as to whether course grained sands make better flooding prospects than fine grained sands. Although coarse sands have demonstrated better flooding properties, it should be recalled that oil saturation after primary recovery is higher in sands of fine texture due to the lower permeability. Additionally, the fine sands usually display a greater uniformity with respect to the important factor of permeability variation discussed above. It is probable that the shape of the sands grains affects oil recovery more than does the size of the grains. The more rounded the grain is, the fewer the dead-ended pore spaces; hence, the more oil is exposed to the flushing action of water.

Limestone and Dolomite

Limestone reservoirs impose more serious restrictions upon flooding operations at the present time judging from past successes. Oolitic or granu-

Profile of a theoretical pay zone of the low relief type of field underlain by water. Most of the productive acre-feet are in the transition zone of higher than normal water saturation.

lar lime certainly may be classified as an excellent medium. Crystalline dolomites are also satisfactory. Pays of mixed composition, the "sandy limes" and the "calcareous sands," are worthy of further consideration.

Fractures

On the adverse side of the ledger should be listed the fractured and vugular limes. Methods tested and proved at the present time are inapplicable. It is hoped that this barrier, at least to some extent, can be broken down through anticipated success with imbibition processes now under test in the Spraberry formation in West Texas. Briefly, imbibition is the capacity of a tight rock matrix to exchange its entrapped oil for water supplied from water-filled fractures in the rock. This form of oil-water exchange is entirely different from the usual ideas concerning the displacement of oil by water. When imbibition is developed into an economically acceptable process, many new opportunities will be opened in the fractured lime provinces such as West Texas.

When fracturing is known to have vertical and consistent directional characteristics, then the opportunity for successful flooding may present itself. In this situation, if water is injected along the strike of fracture planes, it is feasible to place producing wells in parallel lines, so that the injection and producing wells are not directly connected by fractures, and the injected water is then forced to traverse paths perpendicular to the fracture planes. The intervening oil-saturated rock, therefore, is subject to normal displacement action.

Contaminants

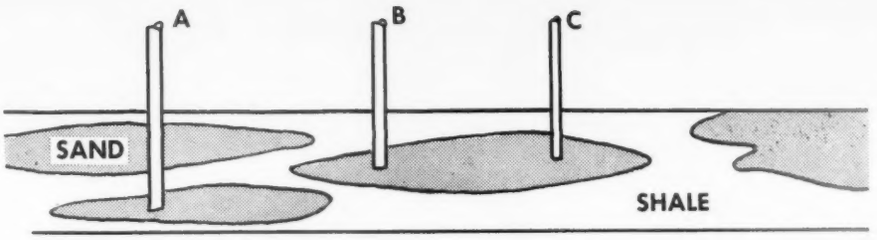
Bentonite

A highly important factor in evaluating a given sand for flooding is its bentonitic content. The percentage of illites and montmorillonites in producing sands relates directly to the floodability of the sand by fresh water. Clay material in sand must be kept in a permanently flocculated state if the sand permeablity is to be retained. Anything causing dispersion of clay reduces permeability. Clay is generally flocculated by brine solutions and dispersed by fresh water. It is apparent that in any area where only fresh water is available particular attention must be given to the clay content of the sand.

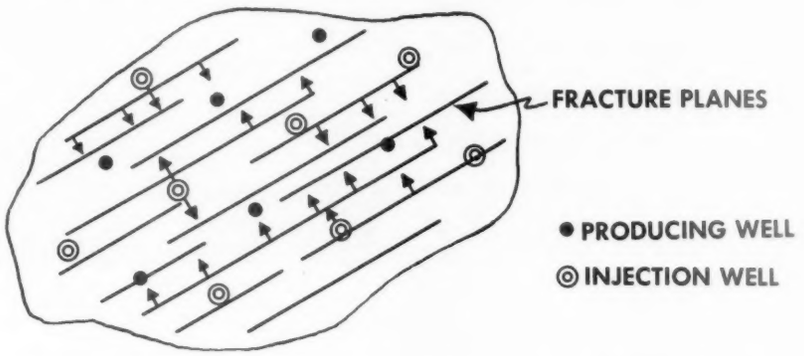
The gamma ray log is a useful tool in the recognition of bentonite. Bentonite is not radioactive itself but is associated with fine silts that contain a high potassium content. Potassium evidences high gamma ray activity. The gamma ray intensity of bentonitic or organic material will exceed that in marine shales, and hence, may be detected easily.

Minerals and Coal

Among the constituents of a formation and its contained fluids, it is advisable to know the pyrite and barium content. Pyrite in the presence of air or oxygen obtained from some previous air drive on the reservoir or from the injection water itself forms corrosive sulfuric acid leading to equipment troubles later on. Barium in combination with sulfates produces insoluble barium sulfate, an exceedingly harmful agent in plugging sand and sharply reducing production. In the Mid-continent area, careful attention is given to the Pennsylvanian system coal streaks, which, being brittle, are subject to fracture upon the application of pressure. Fracturing leads to water by-passing.



Schematic profile of a lenticular-ty;pe reservoir. Well B is connected through permeable sands to Well C, yet is isolated completely from and unaffected by production or injection at the offset Well A.



Fractured formations impose problems. Solution is the placement of similar wells in the direction of fracture planes to force fluid flow through the rock perpendicular to the fractures. Small arrows show water flow out of the fractures into the matrix rock.

The Approach

Various geological factors that have been mentioned in the above were selected because their nature reflects the type of thinking that is used in flood selection work. When an adverse factor is discovered in practice, it does not usually by itself rule out the flood. The effect, rather, is to tighten the requirements in some other category that would compensate such a deficiency. Obviously if, for other reasons, one is not able to compensate for the unsatisfactory reservoir characteristic, then flooding plans can be dropped at an early stage. It is best to attack the least desirable aspects of the project first in order to put the idea on a "go or no go" basis with minimum initial expenditure.

To Be Continued

Next article in this series will deal with the engineering factors in property selection. These are: The flooding process, oil saturation, relative permeability and characteristics of the crude.

The Author

J. Randolph Buck is a consulting petroleum engineer in Dallas, Texas, specializing in oil and gas reserves and related work. Formerly he was associated with DeGolyer and MacNaughton as a reservoir engineer. His previous experience includes service in the field research laboratories of Magnolia Petroleum Company as a senior research engineer and in the petroleum engineering department of The Texas Company. He began his oil career with The Texas Company as a roustabout in South Louisiana following graduation from Worcester Polytechnic Institute, Worcester, Massachusetts, in 1938.

A registered professional engineer in Texas, he holds memberships in the Engineers Club of Dallas, the Petroleum Engineers Club of Dallas and other organizations.

The "208," third ocean-going oil well cementing ship, christened by Halliburton

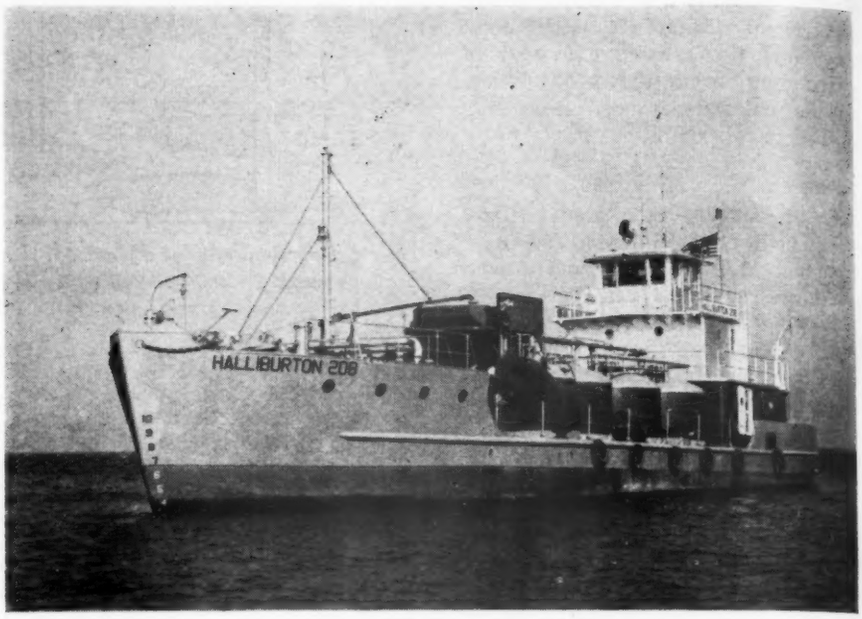


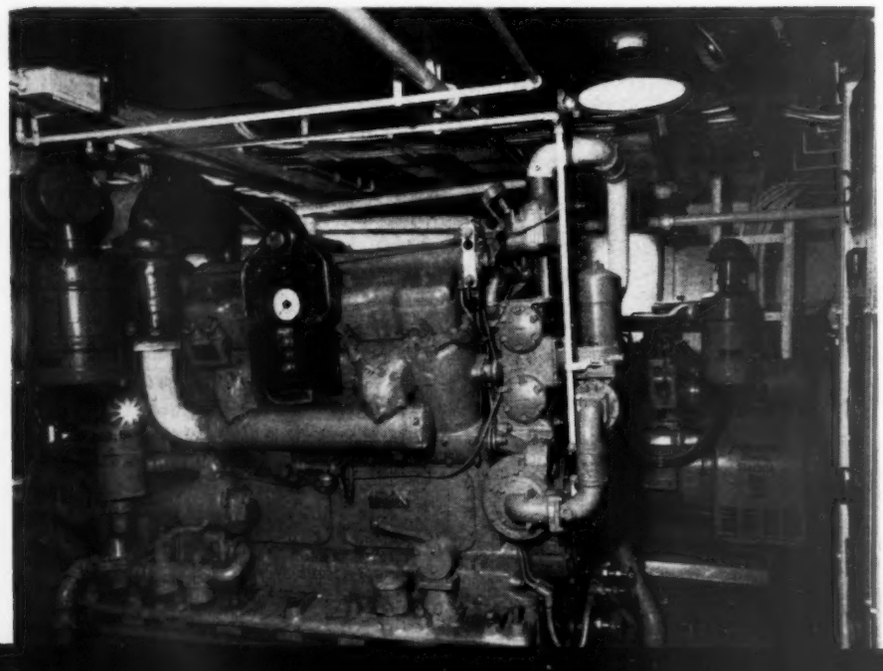
FIG. 1. The "208," third and newest ocean-going oil well cementing ship recently placed in service by Halliburton Oil Well Cementing Company.

Cementing Service Fleet Expanded

THE world's third ocean-going cementing ship, the "Halliburton 208", was commissioned recently at the Southern Yacht Club in New Orleans, Louisiana. The new vessel joins her sister ships, the "206" and the "207" plus a dozen additional vessels designed and used primarily for water operations. The latter group consists of converted LCT's, bulk cement barges, cementing barges, and one vessel equipped for electrical well services.

The "208" is 124 ft long, 31½ ft across her beam, and has a loaded draft of 7 ft-8 in. The twin-screw cementing ship's two 270 hp diesel marine engines give it a maximum speed of 10 knots. Two diesel electric generating sets provide a total of 90 kw electrical power. Besides supplying auxiliary power for the ship, these units drive high-volume, low-pressure air compressors.

FIG. 2. Power house of the "208" consists of these two 270-hp diesel engines that drive the new ocean-going cementing ship at a maximum speed of 10 knots.



Pumping equipment consists of three Halliburton T-10 pumps, each capable of delivering 12,000 psi pressure. Six cone-shaped tanks handle the bulk cement and have a total capacity of 3500 sacks. Normal mixing capacity is 50 sacks of cement per minute using a ribbon blender. The ship is equipped with a weighing and blending device that permits preparation of the cementing material while the vessel is underway. The hold carries 3000 gal of diesel fuel and 6000 gal of fresh water. Short wave radio facilities for communications from shore and other cementing vessels is an important part of the new ship's equipment.

Comfort of the seven-man crew is provided by air-conditioned quarters located forward, away from the ship's engines. The galley is completely electrified, and a lounge located between the pilot house and the main deck is equipped with both radio and television sets.

Mrs. Francis X. deBlanc, wife of Halliburton's marine operations superintendent, commissioned the "208" with the traditional bottle of champagne. ★ ★ ★

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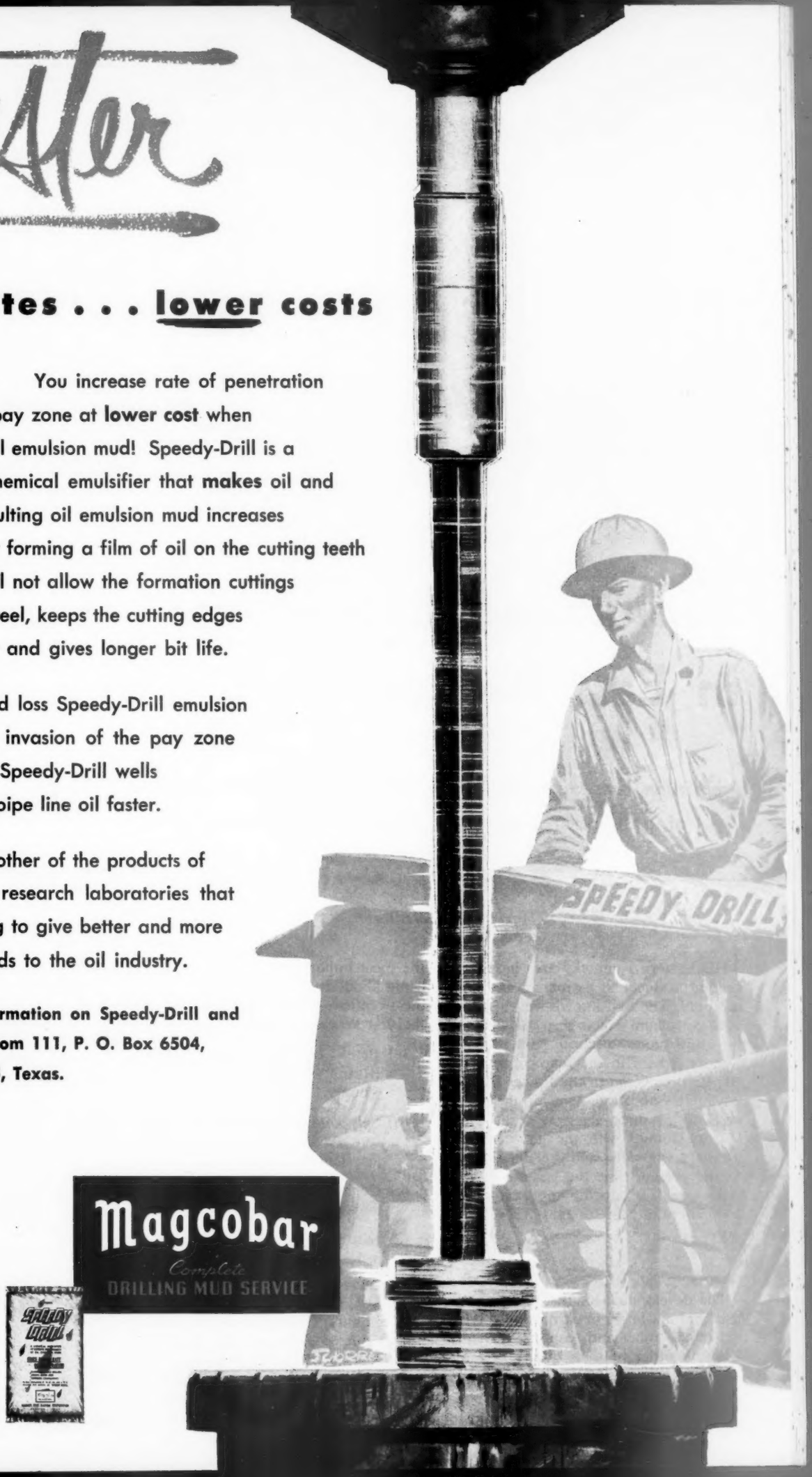

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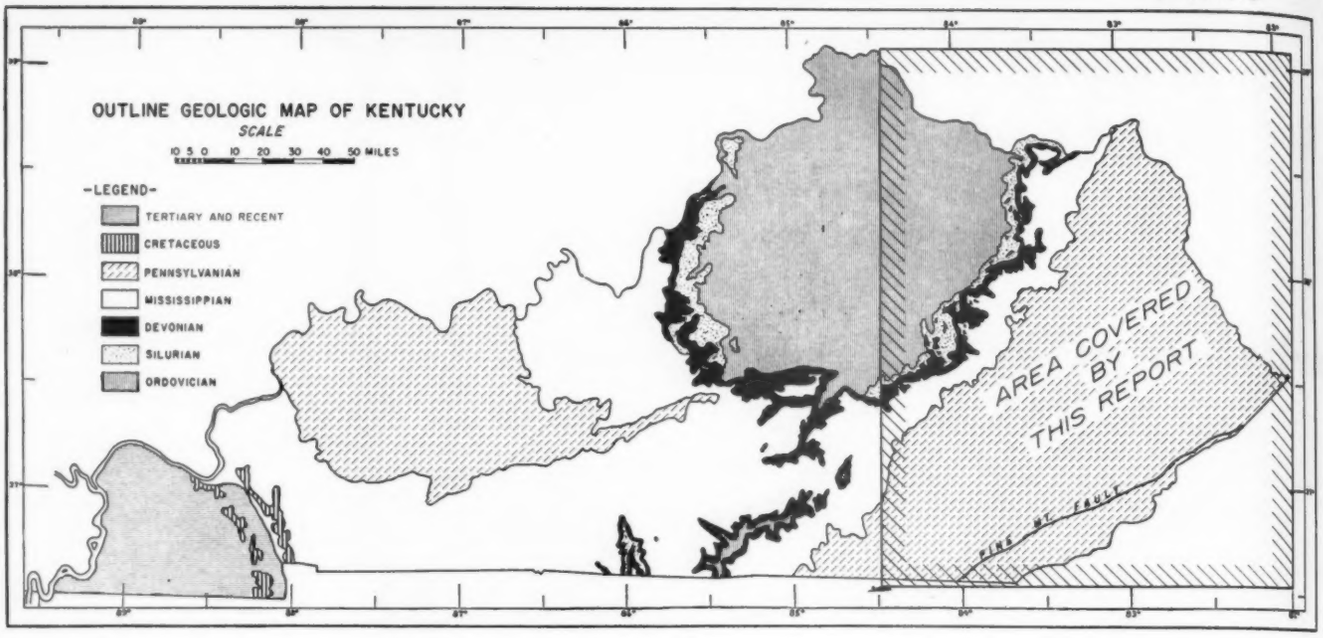

FIG. 1.

Exploration Extensive in East Kentucky

Production runs 5000 bbl a day of oil and 200,000 Mcf of gas—several producing formations have been found

Frank H. Walker*

THE Eastern Kentucky area has long been a producer of petroleum and natural gas. The first known well to produce petroleum in this area was drilled in 1830 near Barbourville, Knox County, where in the search for salt, oil was discovered in the Lower Pennsylvanian Salt Sand. One of the first wells to produce gas was drilled in Martin County with the gas coming from the Big Lime and the Big Injun. At the present time the Eastern Kentucky area is producing approximately 5000 bbl of oil and 200,000 Mcf of gas daily.

History

The development of the oil and gas fields did not begin in earnest until the end of the nineteenth century. Listed below in order of their discovery are the most important developments that came about between the beginning of the twentieth century and the start of the first World War.

(a) Berea oil production on Big Blaine Creek in Lawrence County.

(b) Salt Sand oil production on right fork of Beaver Creek in Floyd and Knott counties.

(c) Corniferous oil production from the Ragland pool in Bath County.

(d) Salt Sand oil and Big Lime gas in Knox County.

(e) Corniferous discoveries in the Menifee Gas pool in Menifee County; Campton pool in Wolfe County; Cannel City pool in Morgan County; and in the Ravenna pool in Estill County.

The developments that came during and soon after this war were as follows:

(a) Corniferous discoveries in Estill, Lee, and Powell counties.

(b) Weir oil and gas in Lawrence, Johnson, and Magoffin counties.

(c) Maxon gas in Pike, Martin, and Floyd counties.

(d) Shale gas in Floyd and Boyd counties.

(e) Big Six gas in Breathitt, Floyd, and Johnson counties.

Since that time no especially outstanding discoveries have been made but development of these aforementioned areas has been carried on with considerable work being done in what is known as the Big Sandy Gas Field. The most recent discoveries in Bell, Harlan, Leslie, and Clay counties need to be developed more before it will be possible to tell just how important they will be.

General Geology and Structure

The rock formations at the surface range in age from Champlainian (Ordovician) in the extreme western portion to Conemaugh (Pennsylvania) in in the area of Boyd and Lawrence counties. An outline geologic map of the state (Fig. 1) is included to give a general idea of the area in which the various age rocks are found. The majority of the area has Pennsylvanian rocks at the surface.

A generalized structure map (Fig. 2) is also included to show the main faults, structural highs, and structural lows of the area. Some of the larger named structures are as follows:

(1) **Cincinnati Arch**—Here is shown only the northeast extension run-

*Geologist, Kentucky Geological Survey.

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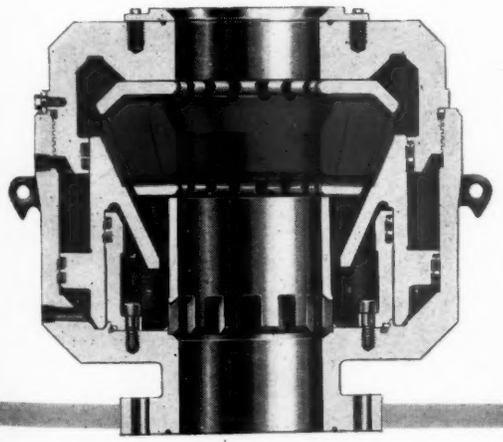

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FIG. 2. Map of Eastern Kentucky showing the main structural features.

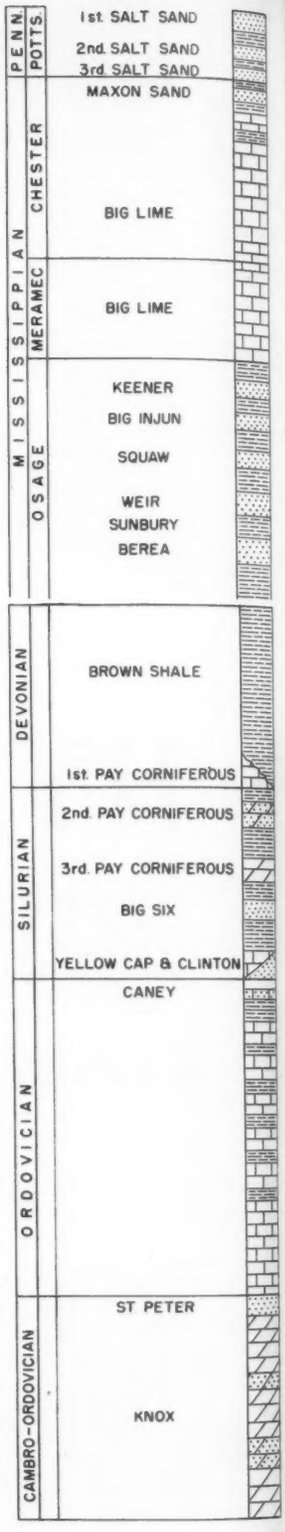

FIG. 3. Generalized section for East Kentucky showing pay zones.

ning through Bourbon, Harrison, and Pendleton counties.

(2) **West Hickman Fault Zone**—This is a zone of normal faulting with a northeast, southwest trend. It is shown on the map in Bourbon, Nicholas, and Mason counties.

(3) **Irvine-Paint Creek Fault and Anticline**—This is an east-west anticline that is associated with normal faulting. It is along this structure that Corniferous oil production has been obtained. This flexure and faulting can be seen on the map in Madison, Estill, Powell, and Wolfe counties and continuing eastward through Martin County where upon entering West Virginia it is the Warfield Anticline.

(4) **Paint Creek Uplift**—In the vicinity of the Magoffin-Johnson County border there is a north-south anticline which crosses the Irvine-Paint Creek structure and forms the Paint Creek Uplift. This structure is quite large and involves some 250 ft of closure. This is an important area of Weir oil and gas production.

(5) **Rockcastle River Uplift**—This is a closed anticline located in Laurel, Clay, and Owsley counties. The anticline is approximately 30 miles long, 10 miles wide, and has a maximum closure of up to 80 ft. Some Corniferous gas and Knox oil has been found on this structure.

(6) **Eastern Kentucky Geosyncline**—This negative structure is a northeast-southwest syncline which is found between Whitley County on the south and Martin County on the east. It has long been termed a geosyncline but in reality it has neither the magnitude nor the make-up of such a regional structure.

(7) **Pine Mountain Overthrust**—This is a large overthrust block that is bounded on the northwest by the Pine Mountain fault, on the southwest by the Jacksboro fault, on the northeast by the Russell Fork fault, and on the southeast by the Hunter Valley fault. Movement along the fault is toward the northwest varying from a distance of two miles on the north to ten miles on the south. This faulted area is found in Whitley, Bell, Harlan, Letcher, and Pike counties.

(8) **Middlesboro Syncline**—This structural low lies just to the southeast of and parallel to the Pine Mountain fault. It is found in Bell and Harlan counties.

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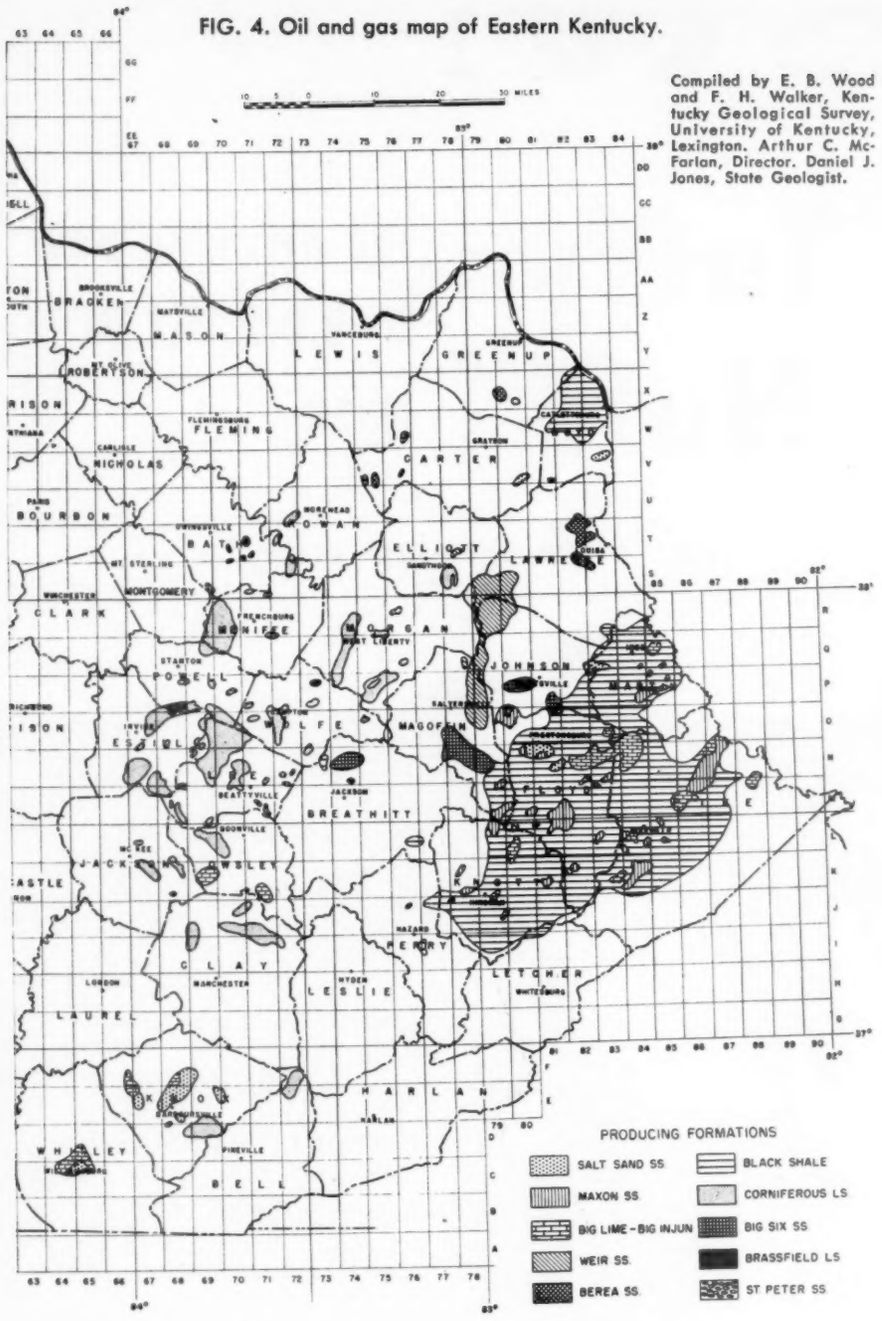
FIG. 4. Oil and gas map of Eastern Kentucky.


Compiled by E. B. Wood and F. H. Walker, Kentucky Geological Survey, University of Kentucky, Lexington. Arthur C. McFarlan, Director. Daniel J. Jones, State Geologist.
PRODUCING FORMATIONS
SALT SAND SS.
MAXON SS.
BIG LIME - BIG INJUN
WEIR SS.
BEREA SS.
BLACK SHALE
CORNIFEROUS LS.
BIG SIX SS.
BRASSFIELD LS.
ST PETER SS.

Producing Formations

A generalized section for eastern Kentucky (Fig. 3) and an oil and gas map of eastern Kentucky (Fig. 4) are included as a guide to the stratigraphic and geographic occurrence of the known pay zones. The section also includes some of the potential yet undiscovered pays.

Salt Sand—The name Salt Sand is a drillers' term for the section at the base of the Pennsylvania System. It is a massive, cross-bedded sandstone with a well developed basal conglomerate composed mainly of quartz pebbles. The sandstone contains only occasional shale partings. This section is Pottsville in age.

In some of the eastern Kentucky areas there are three distinct "breaks." From the top down they are generally known as the First, Second, and Third Salt Sands. In the area of Floyd and Knott counties they are known respectively as the Beaver, Horton, and Pike. In Knox County they are known as the Wages, Jones, and Epperson.

Accumulation is controlled primarily by porosity zones and subordinately by local structure. It is mainly a producer of gas with only a small amount of commercial oil production. Large initial gas flows are encountered but the life of the wells is comparatively short.

Salt Sand production is obtained principally in Whitley, Knox, Boyd, Knott, Floyd, and Johnson counties.

Maxon Sand—The Maxon Sand of eastern Kentucky is a massive quartz sand that is a member of the Pennington or Mauch Chunk formation. It is not to be confused with the Maxton of Ohio since the latter correlates with the lower part of the Salt Sand.

The Maxon is predominantly a producer of natural gas with some oil being found. Just as in the case of the Salt Sand the accumulation in the Maxon is controlled by the development of porosity zones with a subordinate role being played by local structure.

Production from the Maxon Sand is found in Pike, Floyd, Knott, Martin, and Magoffin counties.

Big Lime—The Big Lime, also known as the Greenbrier or the Newman, includes, when the entire section is present, the Fort Payne, Warsaw, St. Louis, Ste. Genevieve, Renault, Paint Creek, and Golconda limestones. It is therefore Osage, Meramec, and Chester in age. The formation is quite thick to the south but as one goes north it thins due both to the loss of its lower three units and the increased effect of the unconformity which occurs at the base of the Pennsylvanian.

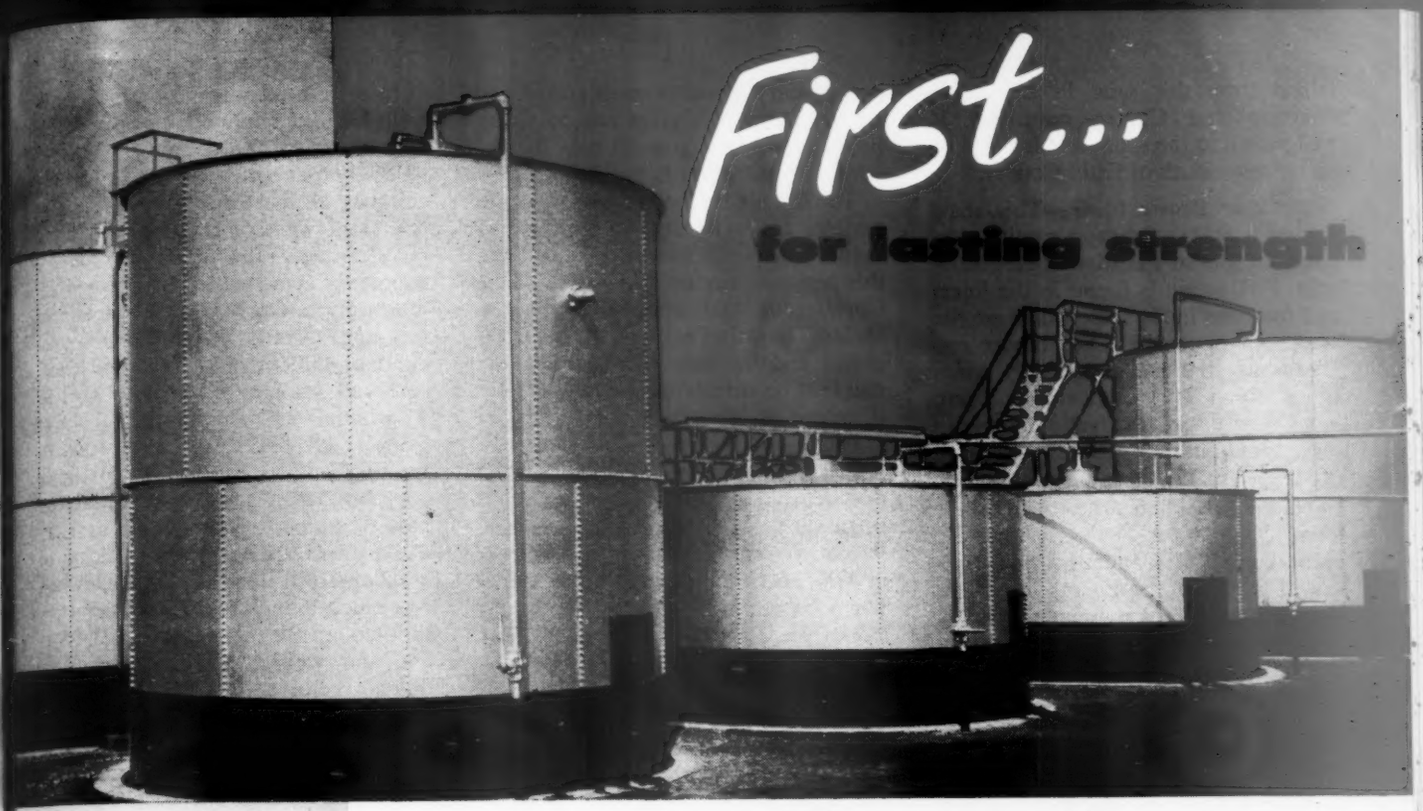
Gas is produced from the Big Lime in Pike, Martin, Floyd, Knott, Knox, Whitley, and Bell counties. Some oil is found in Floyd and Owsley counties. Production is known to occur in cracks and crevices and therefore structure has little or no control over accumulation.

Big Injun—The Big Injun is a red and rather fine-grained sandstone containing much red shale. It occurs in the section just below the Big Lime and is Upper Waverly in age. There are three divisions of this unit known in descending order as the Keener, Big Injun, and Squaw. The base of the Big Lime is often called the Keener where the Fort Payne is present, the chert in the Fort Payne drilling much as does a sandstone.

The Big Injun produces oil and gas in much the same area as does the Big Lime.

Weir—The Weir is a facies development that occurs in the Lower Waverly in northeastern Kentucky. It is a fine to medium textured sandstone of low permeability. It has, however, been a prolific producer of both oil and gas on the Paint Creek Uplift in Johnson, Magoffin, and Lawrence counties. Primary production is long-lived and it responds well to waterflooding. Production is thought to be controlled entirely by structure.

Berea—The Berea is another fine-grained sandstone that is distinguished from the Weir only by the fact that the black Sunbury Shale lies between the two. Long-lived oil production is ob-



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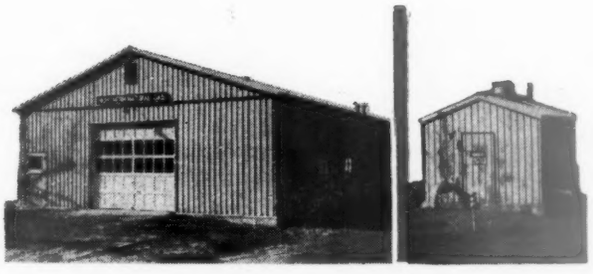

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tained from this sand in Lawrence, Greenup and Carter counties. It wedges out to the south and is not seen on outcrop south of Estill County.

Black or Brown Shale—This shale section is by far the most prolific producer of gas in the eastern Kentucky area. Production is found in the joints and fractures in the shale which are the secondary reservoirs. The primary reservoirs are the silty and sandy zones of extremely low permeability. There is no commercial production found in these zones but they serve as the source of the gas in the secondary reservoirs.

This shale section varies in thickness from 350 to 750 ft. Few shale wells are natural producers and in many cases a well with little or no gas show can be shot into a commercial well. Gas production from shale wells is generally long-lived. There seems to be little relation to present structure and production.

Shale gas is produced in two main areas. There are the Ashland Field in Boyd and Greenup counties and the Big Sandy Field in Martin, Johnson, Pike, Floyd, Magoffin, and Knott counties. The Big Sandy Field is currently being extended southwest with some little production being found in Perry and Leslie counties.

Corniferous—The Corniferous as used in Kentucky denotes the producing limestone zones below the Brown Shale. These zones vary in age from Boyle (Hamilton) to Lockport (Niagaran).

The Corniferous on outcrop varies from 0 to 32 ft thick. The formation thickens to the east as it goes under cover with a maximum thickness of approximately 600 ft in Lawrence County.

This zone has been an outstanding producer of oil and gas for many years. Production is governed by many factors, the principal one due to permeability created by weathering prior to deposition of the overlying Brown Shale. Facies changes and unconformable relationships also have much to do with the occurrence of the oil and gas. Producing zones in the Corniferous have been found in the Hamilton (Devonian), Huntersville (Devonian), Salina (Devonian), and Lockport (Silurian).

Rather than try to list all of the counties from which the Corniferous either has or is producing, the reader is referred to the oil and gas map of eastern Kentucky (Fig. 4).

Big Six—This is a quartz sand of Silurian age. It is a producer of gas in Breathitt, Magoffin, Johnson, and Floyd counties. Accumulation is governed primarily by the development of porous and permeable zones and second by structure. This gives rise to spotty production. As a general rule the decline in production is rapid.

The Big Six has been correlated with various zones in the Corniferous by many writers. Others have stated that this pay zone occurs at the base of the Corniferous and above the Clinton shales. The writer agrees with the latter group and he feels that the Big Six can best be correlated with the Keefer (Clinton) of West Virginia.

Clinton—The Clinton sand has not been an important producer of oil and produces no gas in Eastern Kentucky. It cannot be entirely ignored, however. It has produced a little high-grade oil in Morgan County and is quite a prolific producer in Ohio. It is the correlative of the Brassfield or Yellow Cap of Eastern Kentucky and the White Medina of West Virginia.

Yellow Cap—The Yellow Cap of the driller is the Brassfield, a yellow porous and cherty dolomite. The only production from it has been a little oil from both Wolfe and Bath counties.

Caney—The Caney has produced only a little gas and some light oil in both Bath and Wolfe counties. It is a light-colored sugary dolomite with a small amount of sand. It is not considered an important producer.

St. Peter—The St. Peter sandstone, where present, has been used to mark the boundary between the Chazy-Black River and the Knox. There is some doubt that this sandstone is the correlative of the true St. Peter but it is so firmly entrenched in usage that it will probably not be replaced.

The St. Peter has produced gas in only one area to date. This area is located along the border of Powell and Estill counties and is known as the Furnace Field. There were 14 wells drilled in this area of which 11 were producers and 3 were dry. The gas, unfortunately, contained 40 per cent carbon dioxide and was not used commercially.

Knox—The Knox in Kentucky is by far the greatest potential oil and gas producer that is as yet relatively untouched. Quite a bit has been written and said about the several hundred Knox tests that have been drilled, mainly in the central portion of the state. When one begins to determine just how well the Knox has been tested he finds that at least 90 per cent of these wells have penetrated no deeper than the top 100 ft. Only one well in Kentucky has ever reached the basement complex. It is quite evident on this basis that the possibility for oil and gas in this thick section of predominantly dolomites with few scattered sandstones cannot be ignored.

In eastern Kentucky only two Knox wells have encountered any appreciable amounts of oil. These two were drilled on the border between Clay and Laurel counties on the Rockcastle River Uplift. Both wells were drilled by Pure Oil Company and Stanolind and encountered some oil in the Knox dolomite section. The No. 1 J. C. McKnight in Laurel County was drilled to a total depth of 4539 or 1235 ft into the Knox. The well was plugged back to 3541 ft. The initial production was 14 bbl of oil per day. The well was produced from December 16, 1947, to November 10, 1948, when it was abandoned. The No. 1 Gilbert Hammonds in Clay County was drilled to a total depth of 4002 or 618 ft into the Knox. This well was plugged back to 3693. A defective shot collapsed the casing at 2986 ft and the well was abandoned even though there was 2575 ft of oil in the hole at 3595 ft.

Several sands that would be capable of carrying oil have been encountered in scattered wells in the eastern portion of the state. Some have been named and some have not. Until considerably more drilling is done it will not be known whether these sands are small isolated lenses or whether they cover considerable area.

Recent Developments

The area of southeastern Kentucky is at the present time being explored rather extensively.

Along the border of Clay and Leslie Counties The United Fuel Gas Company has leased the 113,000-acre tract of the Fordson Coal Company. A total of 25 wells are to be drilled on this tract in its initial development. Several wells that have been drilled have encountered some gas in the Corniferous but, due to the lack of pipe line facilities, no gas has been sold.

In the Kettle Island area in northeastern Bell County the North American Petroleum Company has drilled several wells that are producing gas from the Big Lime and the Corniferous. At the present time a pipe line is being laid that will tie to lines serving Pineville and Middlesboro.

It is reported that a well drilled in Harlan County has encountered a good flow of gas in the Corniferous. If enough gas is found by drilling other wells in the vicinity a line will most probably be installed to market the gas.

At the present time there is a well being drilled on Brownies Creek in Bell County. It is rumored to be a Corniferous test. If this is true it will be the first well in Kentucky to penetrate the Pine Mountain Thrust Fault and could conceivably open a large area that is as yet untouched. * * *

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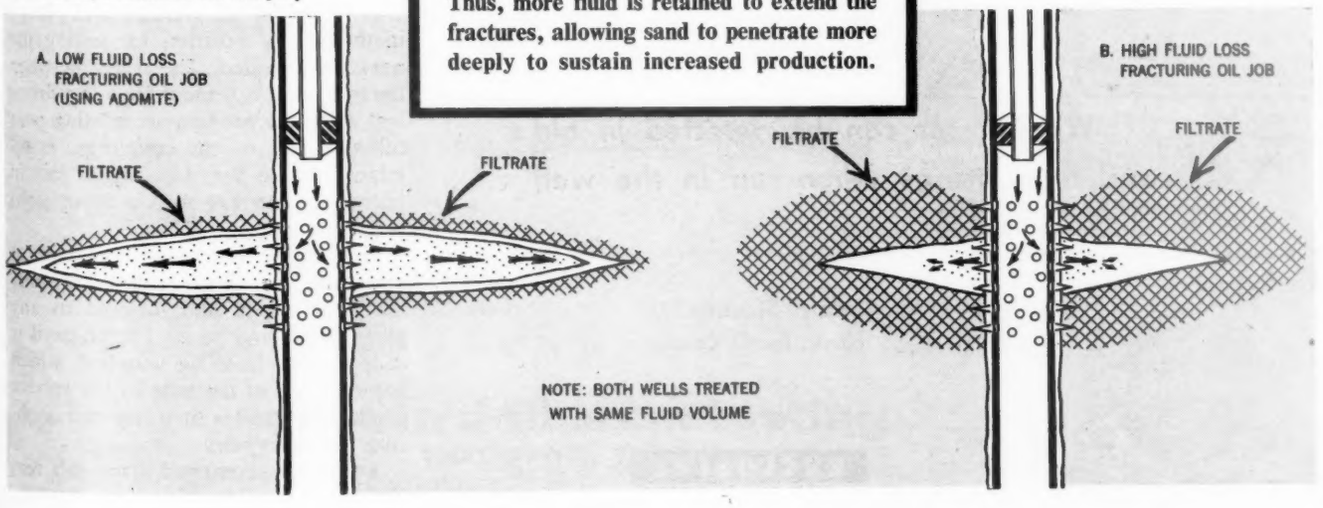
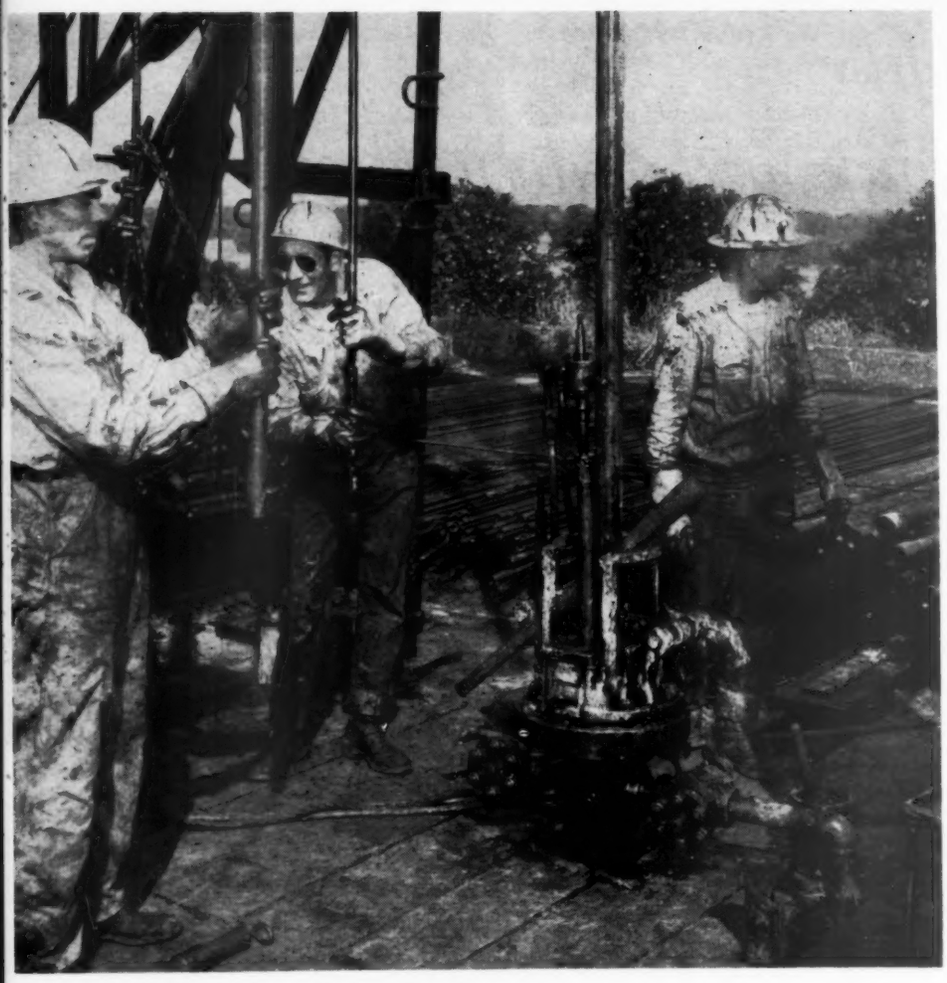

A. LOW FLUID LOSS FRACTURING OIL JOB (USING ADOMITE)
FILTRATE
FILTRATE
B. HIGH FLUID LOSS FRACTURING OIL JOB
FILTRATE
FILTRATE
NOTE: BOTH WELLS TREATED WITH SAME FLUID VOLUME



"Quick-change" head in position, tubing is under pressure. Area tested at each position comprises two lengths and three couplings. As a safety factor tubing is pressurized below surface.

Simplified Method Tests Tubing

Weaknesses can be detected in old and new strings when run in the well

Jerry Stumm
Editor, Pacific Coast

EXCLUSIVE

ALTHOUGH the principle of internal hydrostatic pressure is not new, having been used for years in tube mills and in the field on pipe racks, a simplified method of testing tubing after it is made up in the string and is being run in the well provides a speedy means of detecting weakness.

The reasons for testing old tubing being rerun in a well are obvious, generally for the purpose of locating deterioration and trouble known to exist. During the last two years, however, this method of field testing has been used more and more for the purpose of testing new tubing direct from the mill. It has been found that some types of defects, although not discernible at the mill, do show up after handling, and are brought to light by this method of field testing. Also, thread lubricants and proper make-up are beyond the control of the manufacturer of the tubing.

Method Described

The main advantage of this method of tubing testing is that all collar and pin threads are tested in their made-up position while the crew is running the tubing in the well. A retrievable plug consisting of top and bottom packers, joined together by a stand of sucker rods, is lowered into the tubing until the bottom packer is below the made-up joint. Then the area between the top and bottom packer is filled with water and pressure applied by means of a ram, located on the service truck, and this pressure held for a few seconds. The loss of only a few drops of water will register on the pressure gage and indicates a leak. When a loss of pressure occurs the stand is pulled above the derrick floor, with the pressure retained, and a visual check instantly finds the leak.

If a stand passes the test, the quick change head is removed, the next stand added to the string and lowered to the slips. The testing assembly, which has been lowered with the previous stand, is retrieved by an overshot and placed in the proper position for testing the next stand added. The water between the two packers, except for a few drops lost while the packers are passing over tubing ends in the couplings, is retained for the next test. Water lost in testing the average well is about eight to twenty gal.

If tubing repairs are necessary at any time the entire testing assembly may be tripped and lowered to any given depth and reset. The go-devil is dropped to release the wire line, which is pulled out of the hole by the service truck. The stand is then free and unobstructed for repairs.

Table 1 is compiled from job rec-

FOR MORE INFORMATION AT THE BOTTOM OF YOUR WELL

Double Shut-In Pressure Readings Provide More Information — In Less Time — Than Other Methods

"WHAT IS THE main advantage of double shut-in pressure readings?" That's a question often asked by those who have not yet tried this newest method of drill stem testing.

Actually there are *four* main advantages of the double shut-in pressure method:

1. Maximum formation pressure build-up in shortest time.
2. Comparison of reservoir build-up pressures before and after test.
3. Two separate chances to obtain reservoir pressure.
4. The measuring of the true equilibrium pressure prior to producing the formation provides a virgin pressure measurement and more accurate data.

Perfected by Johnston Testers, this new technique requires only a simple rearrangement of the test tool assembly. By placing a disc valve above the main or hydraulic valve, a specified volume of air is trapped between these two valves. This volume of air is called the "air chamber."

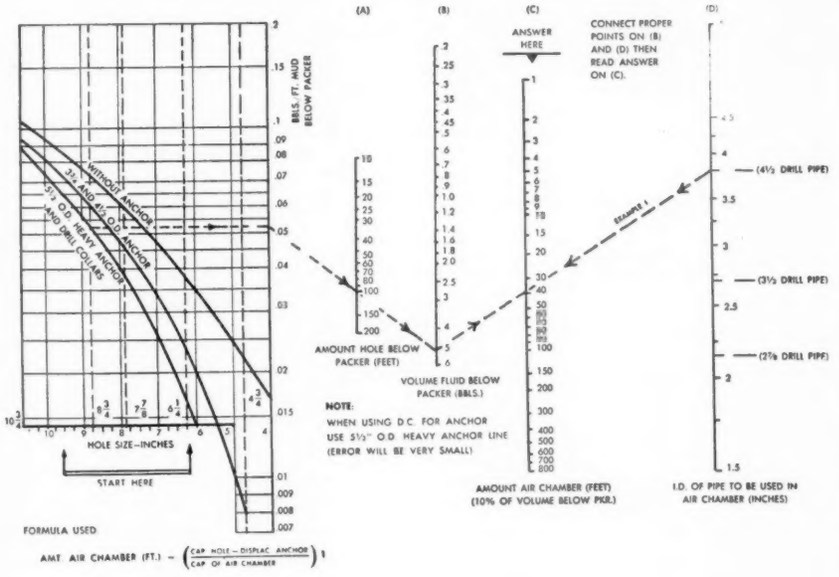
As the purpose of the air chamber is to relieve the mud pressure trapped below the packer, the secret of success of double shut-in testing is accurate use of this air chamber. Best results have been obtained when volume of the air chamber is about 10% of the volume of mud below the packer.

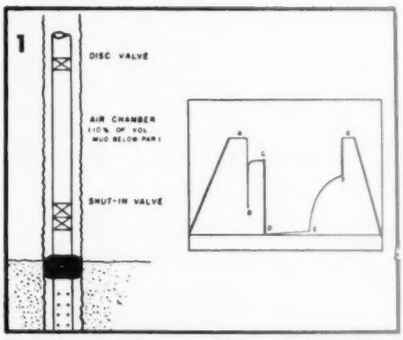
In the past, it has been common to calculate the air chamber to the nearest 30-foot pipe length. This lack of accuracy has often caused a failure to record the *maximum* initial shut-in pressure.

To overcome this problem, and to do away with complicated mathematics, Johnston has developed an "air chamber alignment chart." By simply drawing straight lines between known figures, the amount of air chamber needed can be calculated quickly and accurately.

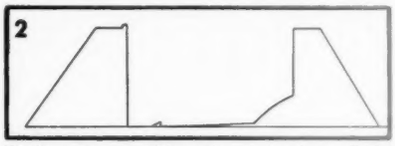
The chart below shows how simple it actually is to use this method.

Complete information on double shut-in testing is available from Johnston Testers, Houston, Texas. Write today for complete descriptive folder.

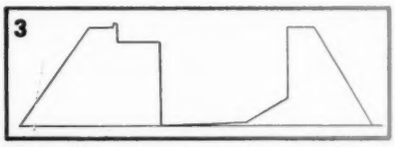

(A)
(B)
(C)
(D)
ANSWER HERE
CONNECT PROPER POINTS ON (B) AND (D) THEN READ ANSWER ON (C).
BBLS. FT. MUD BELOW PACKER
WITHOUT ANCHOR
3½" AND 4½" O.D. ANCHOR
5½" O.D. HEAVY ANCHOR AND DRILL COLLARS
HOLE SIZE—INCHES
START HERE
AMOUNT HOLE BELOW PACKER (FEET)
VOLUME FLUID BELOW PACKER (BBLS.)
EXAMPLE
(4½ DRILL PIPE)
(3½ DRILL PIPE)
(2⅞ DRILL PIPE)
NOTE:
WHEN USING D.C. FOR ANCHOR USE 5½" O.D. HEAVY ANCHOR LINE (ERROR WILL BE VERY SMALL)
AMOUNT AIR CHAMBER (FEET) (10% OF VOLUME BELOW PKR.)
I.D. OF PIPE TO BE USED IN AIR CHAMBER (INCHES)
FORMULA USED
AMT. AIR CHAMBER (FT.) = (CAP. HOLE − DISPLAC. ANCHOR / CAP. OF AIR CHAMBER)



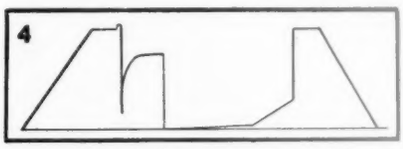
Testing tool assembly for double shut-in pressure readings which permits a limited fluid withdrawal. By placing the disc valve above the main or hydraulic valve so that a specified volume of air is trapped between these two valves.



Well not capable of producing fluid fast enough to fill up air chamber and cause pressure build-up.



Mud did not expand enough to get pressure draw-down below the formation pressure.



Mud expanded and pressure draw-down was below the formation pressure. Well was able to flow enough fluid to fill up air chamber and build-up shut-in pressure.

JOHNSTON TESTERS

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HOUSTON, TEXAS

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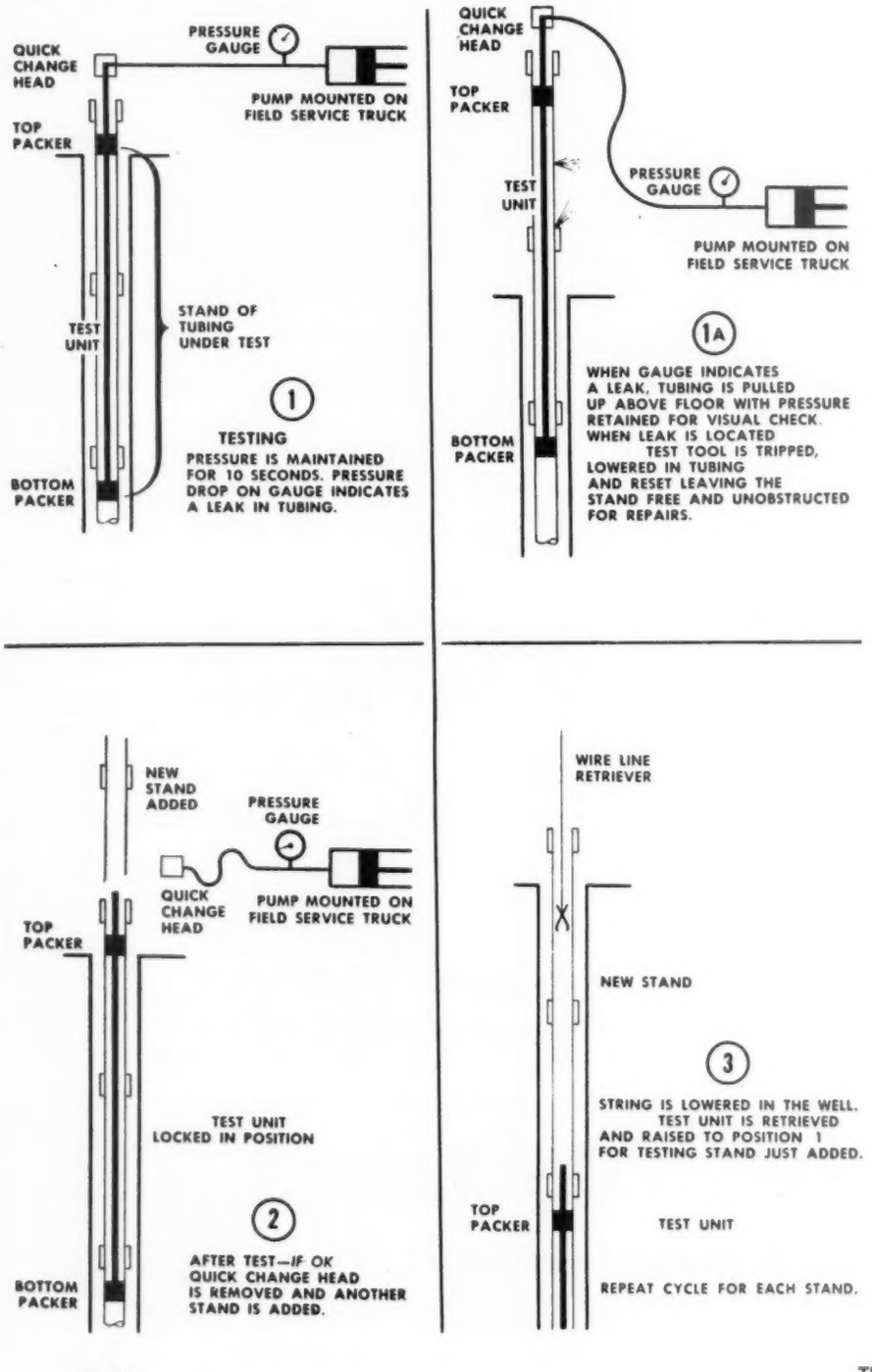
FORMATION AND CASING TESTING — JOHNSTON

TABLE 1. Hydraulic testing of 12 parallel strings during February, 1954
Total leaks found—63

Ticket Number	Depth feet	Joints laid down	Collar leaks	Split leaks	Test on pumps
3490	5850	None	2—2½″	1—2½″ at 3600#	ok
3540	6475	1—2½″ cutout	2—2½″	1—1¼″ at 4000#	ok
3542	6215	4—2½″ bad thread	8—2½″	1—1¼″ at 4500#	ok
3562	6500	None	None	None	ok
3543	6370	None	1—2½″	None	3 pumps leaked
3496	6410	1—2½″ cutout joint	1—2½″	1—1¼″ at 5000#	ok
3544	6210	None	1—2½″ 12—2½″ new pipe	None	ok
3499	6320	1—¼″ joint with welded bead. 1—Donut leaked on top of 2½″ tubing.	1—2½″	1—1½″ at 3300#	1 x 1¼″ cross-over leaked
3545	6080	2—2½″ cutout	3—2½″	None	ok
3500	6290	2—2½″ collar leaks	6—2½″ new pipe 1—2½″	None	ok
3546	6380	None	2—2½″	1—2½″ at 800#	ok
3602	6240	1—1¼″ knock-out plug collar leaked both top and bottom		None	ok

ESSENTIAL steps involved in hydrostatic testing tubing as it is run in the well


QUICK CHANGE HEAD
PRESSURE GAUGE
PUMP MOUNTED ON FIELD SERVICE TRUCK
TOP PACKER
TEST UNIT
STAND OF TUBING UNDER TEST
1
TESTING
PRESSURE IS MAINTAINED FOR 10 SECONDS. PRESSURE DROP ON GAUGE INDICATES A LEAK IN TUBING.
BOTTOM PACKER
QUICK CHANGE HEAD
TOP PACKER
PRESSURE GAUGE
TEST UNIT
PUMP MOUNTED ON FIELD SERVICE TRUCK
1A
WHEN GAUGE INDICATES A LEAK, TUBING IS PULLED UP ABOVE FLOOR WITH PRESSURE RETAINED FOR VISUAL CHECK. WHEN LEAK IS LOCATED TEST TOOL IS TRIPPED, LOWERED IN TUBING AND RESET LEAVING THE STAND FREE AND UNOBSTRUCTED FOR REPAIRS.
BOTTOM PACKER
NEW STAND ADDED
PRESSURE GAUGE
QUICK CHANGE HEAD
PUMP MOUNTED ON FIELD SERVICE TRUCK
TOP PACKER
TEST UNIT LOCKED IN POSITION
2
AFTER TEST—IF OK QUICK CHANGE HEAD IS REMOVED AND ANOTHER STAND IS ADDED.
BOTTOM PACKER
WIRE LINE RETRIEVER
NEW STAND
3
STRING IS LOWERED IN THE WELL. TEST UNIT IS RETRIEVED AND RAISED TO POSITION 1 FOR TESTING STAND JUST ADDED.
TOP PACKER
TEST UNIT
REPEAT CYCLE FOR EACH STAND.

ords for one producer and shows the results of hydrostatic testing of new tubing for wells being converted to a hydraulic free pump system. In this installation the test pressure was 5000 psi. The time consumed for testing a stand is 45 sec or less, and extends the tour of the service crew from one to two hours, depending upon the number and type of repairs required.

Leaks in New Tubing

Many authorities have discussed the effectiveness of proving a joint with high internal pressures for short periods, holding to the theory that new tubing and couplings, whose threads are within the API tolerances, will not leak if a minimum amount of caution is used when the stand is made up. It is asserted that pipe thread lubricants will seal effectively for short periods of time when first applied, and fail only after several hours of stress; however, Table 1, covering twelve jobs on parallel strings, where new tubing was used, shows a surprising number of collar leaks through threaded sections and lubricant. The reason for these factory-perfect threads not being tight when made up was not definitely determined. The equipment was modern, and the crew experienced. The consensus resulted in two possible conclusions. First, while precautions were taken in the delivery of the tubing, the shipment could have been mixed and consequently some may not have been mated perfectly. Second, the handling factor was considered, and is considered the principal reason for leaks in new tubing. It will be noted from the table that on these jobs the collar and thread leaks were limited to the 2½ in. tubing, whereas the 1¼ in. macaroni strips made up tight in every joint.

Salvaging Old Tubing

Many users have found hydrostatic testing a means of salvaging used and rerun tubing. The tubing marked doubtful by caliper test is often set aside or discarded. On the theory that remaining wall thickness is not always a true criterion of the ability of tubing to withstand internal pressures, hydrostatic testing provides an additional means of selection. It has been found that in some cases as much as 70 per cent of the doubtful tubing has been salvaged by hydrostatic pressure testing at reduced pressures, then placing salvaged tubing in top half of string.

Hydrostatic testing also will locate leaks such as pin holes, cut threads, and cracks that have been passed in a caliper test. It is indicative that caliper testing alone is not conclusive in all cases, but is helpful in eliminating tubing that is not worth a hydrostatic pressure test. ★ ★ ★

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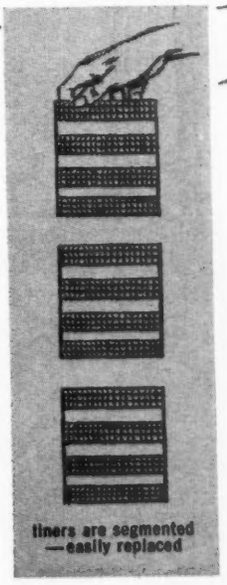

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To obtain more information on products advertised see page E-27

Carter's Experience in Arkansas . . .

Drilling With Engine Exhaust Gases

Here's what they learned . . .

- **Adequate volumes available**
- **Penetration rates increased**
- **Drilling costs can be reduced**
- **Gas can be treated for corrosion**

Rock dust from the bottom of the well piles up at Carter's engine exhaust gas drilling project in Conway County, Arkansas.

Charles B. Erbe

A UNIQUE application to rotary drilling by utilizing engine exhaust gas as a circulating fluid was employed successfully by The Carter Oil Company at the Carter et al J. H. Jones No. 1, a recent Conway County, Arkansas, wildcat well. Altogether, three intervals or a total of 1862 ft were drilled in this well with exhaust gas. The unusually hard and well-compacted formations present in this locality prompted the use of a gas phase drilling fluid in an effort to increase penetration rates and reduce drilling costs. Natural gas for this purpose was not economically available. In the absence of sufficient knowledge concerning down-the-hole hazards in the use of air, attention was directed to exhaust gas. The large volume of exhaust gas, with its relatively low oxygen content, which can be obtained from the rig and compressor engines, make it a potentially desirable circulating fluid. It was felt that the main disadvantage of exhaust gas would be its corrosiveness, although reduction of water content and use of inhibitors offered comfort in this problem. From this application of exhaust gas drilling, it has been shown that treatment of gases for this use is practical, improved penetration rates and reduced drilling costs are attainable, and adequate exhaust gas volume is available from the rig and compressor engines.

Application of exhaust gas drilling at the Jones well was prompted by expected slow penetration in hard formations, as experienced in two wildcat wells drilled by Carter using conventional mud systems, and by faster drilling with air by another operator in the area. Although differences in lithology partly explain the improved drilling obtained by the operator in this

instance, an attractive advantage was indicated for exhaust gas drilling.

Exhaust Gas Processing

Equipment was designed and installed by Carter at the Jones No. 1 for cooling, separating liquids, compressing, and measuring exhaust vapors as shown by Fig. 1. Major items included two atmospheric coolers, two heat exchangers, two separators, and three portable compressors. The drilling rig was equipped with two 325-hp gas-fueled engines.

The system utilized as much exhaust gas as possible from the two natural gas-fueled rig engines, with the balance of exhaust vapors supplied by diesel-fueled compressor engines and supplemental make-up air required. Exhaust gas was processed through the equipment shown in Fig. 2 and metered prior to going to the standpipe on the rig floor. Cooling water for the unit was taken from a nearby pond. All processing equipment could be dismantled and moved to a new drilling location, or portions of it salvaged for use in conventional oil field operations.

Compressor facilities consisted of two 600 cfm and one 315 cfm, portable rotary compressors, Fig. 3, having a combined capacity of 1515 standard cfm at 100 psi. These units were powered by two 90-hp and one 45-hp diesel engine, all directly connected to the compressors. Fuel consumption was approximately 508 gal per day. Rental compressors were utilized because the requirement was of short duration.

Exhaust Flow Line

Exhaust vapors, dust, and cuttings were conducted away from the rig through 240 ft of 7-in. outside diameter flow line as depicted in Fig. 4.

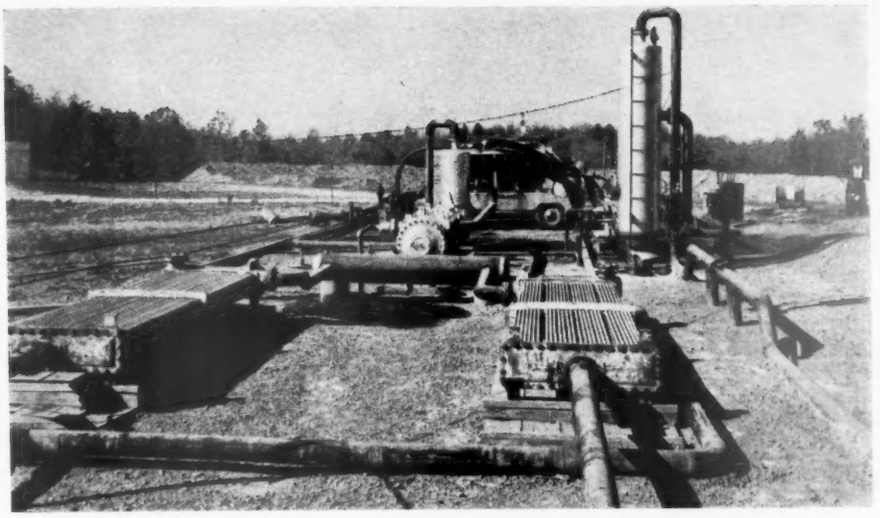

FIG. 2. Engine exhaust gases were cooled and moisture removed by two atmospheric coolers, two heat exchangers, and a conventional separator. Cooling equipment was surplus material from a gasoline plant.

Sample cuttings were taken from a catcher on this line. The end of the flow line was equipped with a spray; however, this was unsatisfactory since the dust discharged while cleaning the hole plugged the water ports. A flare was provided so that any gas produced would be ignited.

Wellhead Equipment

Slight modification of conventional rotary wellhead equipment, as shown in Fig. 5, provided adequate control for vapor-phase drilling. A conventional double-gate type mechanically operated blowout preventer was used, together with a rotating stripper head for sealing off around the kelly. The stripper head was kept well lubricated to prevent leakage of gas.

Drilling Technique

Circulation of vapors was controlled by the standpipe valve on the rig floor. Closing this valve stopped circulation, and the compressors automatically unloaded within seconds. Connections

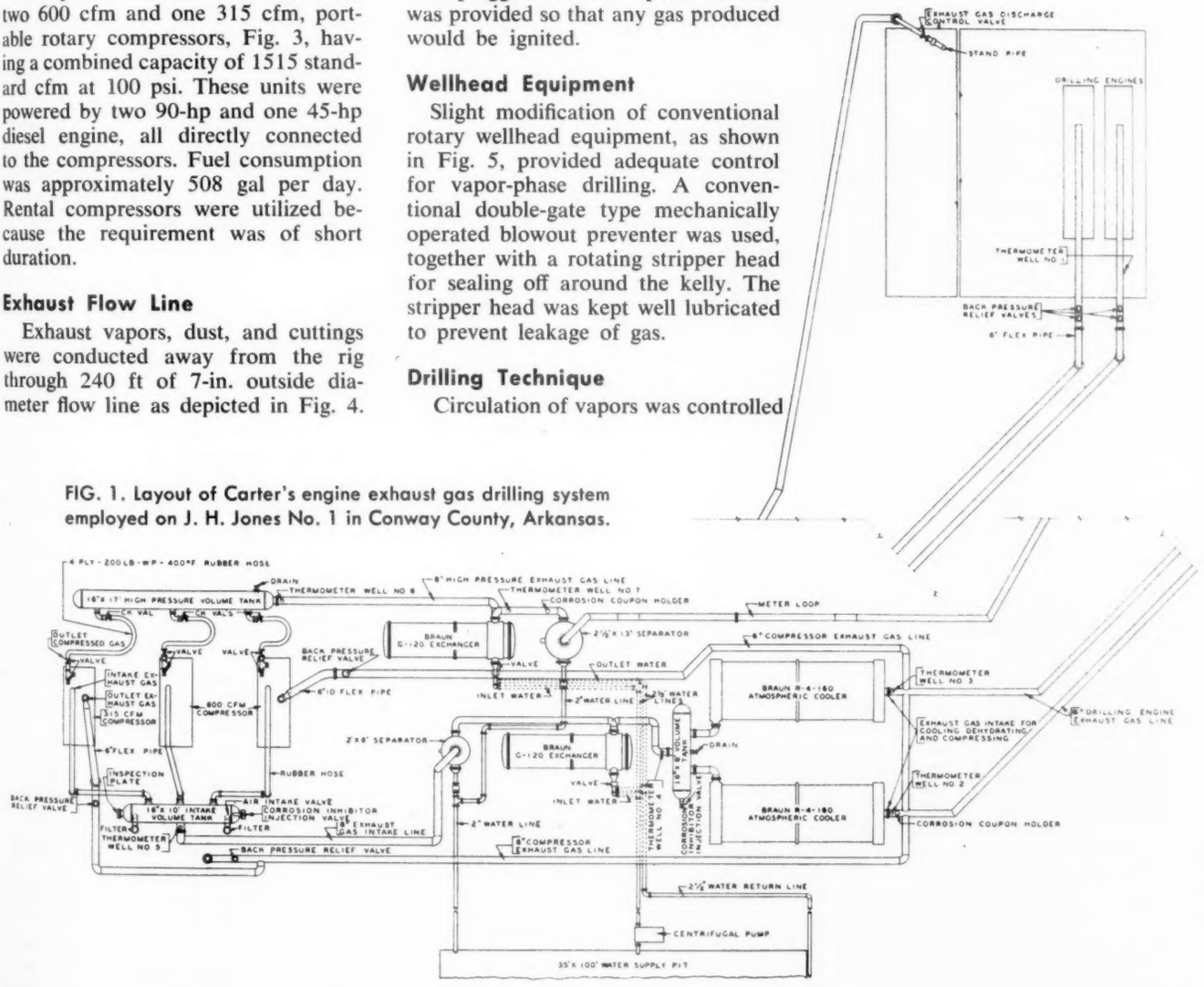

FIG. 1. Layout of Carter's engine exhaust gas drilling system employed on J. H. Jones No. 1 in Conway County, Arkansas.

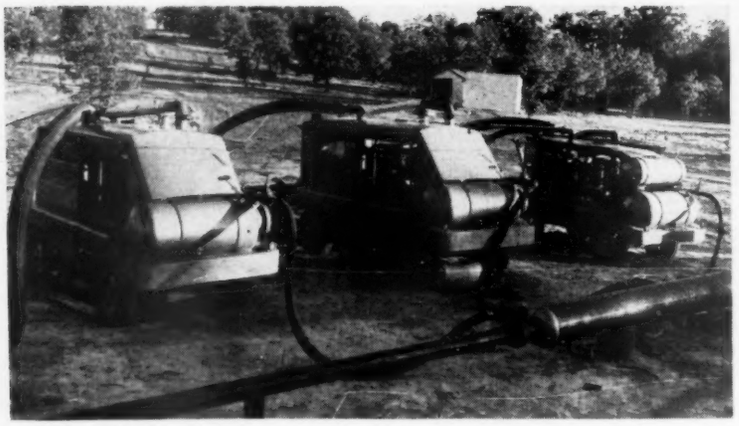

FIG. 3. Three compressors provided a combined capacity of 1515 standard cubic feet per minute at 100 psi. Exhaust gases from the driving engines were combined with the exhaust gases from the drilling rig engines to make up the required volume.

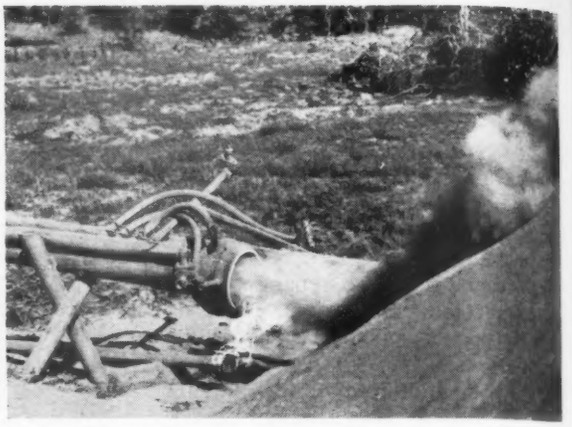

FIG. 4. Discharge nozzle from 7-in. line is located at a safe distance from the rig. Flare will ignite any produced gas encountered during the drilling.

were made by stripping the kelly and a drill pipe single through the rotating stripper head in place. When making round trips, the stripper head was set back with the kelly. It was necessary to circulate near bottom for approximately 15 minutes before starting a round trip in order to clean the hole. Even so, there was a fill-up of several feet of cuttings after each shutdown. The cuttings, however, became quite fluid when circulating was resumed and it was possible to return to bottom without rotation.

Several drilling conditions were accurately and quickly indicated by the exhaust gas. Returns were seen within seconds after circulation was begun. Dust in the exhaust indicated that cuttings were being lifted, and an abrupt stoppage of cuttings or dust indicated moisture in the hole or a plugged bit. Required weight on the bit was considerably less while drilling with vapors than was necesssary during mud drilling operations.

Exhaust Gas Operation

Application of exhaust gas drilling on the Jones No. 1 was limited by various circumstances to three intervals, 421 ft to 506 ft; 3344 ft to 3592 ft, and 3609 ft to 5138 ft, a total of 1862 ft. In each case, drilling was increased over that of mud for the interval above, with the last interval being penetrated at a rate of 11.49 ft per hour. Based on this penetration rate, the increase in drilling rate as compared with a mud-drilled well in the same interval was 475 per cent greater.

Another important characteristic of exhaust gas drilling observed was the increased bit life. In each of the above cases, bit performance was improved. An unusual single-bit run of 723 ft was achieved while drilling with vapors. Improved bit life was 1325 per cent greater than that obtained from a comparable well of the same interval with mud as the circulating medium.

It is believed that two factors contributing materially to the increased penetration rates and longer bit life experienced with vapor drilling are: (1) Faster removal of cuttings from beneath the bit, and (2) less rock compaction due to the difference in hydrostatic head of mud as compared to the weight exerted on the formation by a column of gas.

Performance of the exhaust gas system was generally satisfactory. The gas volumes were sufficient, being measured at an average of 2.5 MMCF per day, and the capacity of the processing equipment was adequate. In addition to the gas being cooled from 950 F to 90 F and being compressed from 0 psi to 60 psi, the gas was passed through a separator to remove free water and other liquids.

Corrosion, one of the principal problems, became apparent in the system although some success was obtained using corrosion inhibitor. Test coupons indicated a corrosion rate of 11 mils per decimeter per day in the low-pressure side and 70 mdd in the high-pressure side of the system. A method of injecting the inhibitor in the high-pressure side should alleviate this condition.

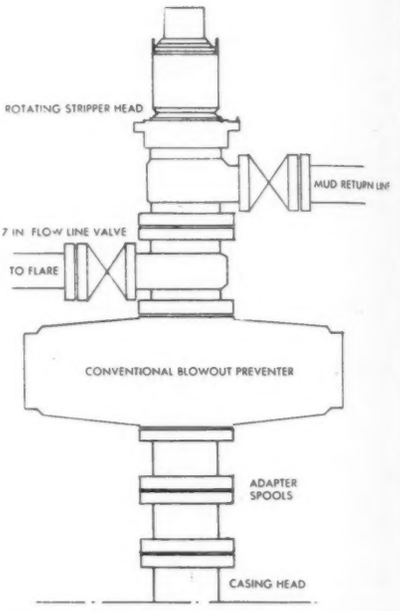

FIG. 5. Schematic diagram of wellhead.

Based on this initial operation of exhaust gas drilling, the following conclusions can be drawn:

(1) Exhaust gas volume from the rig and compressor engines is adequate for use as a circulating medium for rotary drilling.

(2) The hole must be completely dry for suitable operations.

(3) Improved bit performance and penetration rates compared with those for mud drilling are indicated.

(4) Exhaust gas can be treated for continuous use; however, successful solution of the corrosion problems will require further experience. * *

The Author

Charles B. Erbe is a petroleum engineer for The Carter Oil Company at its Purcell, Oklahoma, district office. Prior to joining Carter in February, 1953, he was an assistant instructor in the petroleum engineering department at the University of Oklahoma, where he was graduated earlier with a BS in petroleum engineering. He served as engineer on Carter's exhaust gas drilling project in Conway County, Arkansas, which project he describes here, and presented a talk on the project before the Oklahoma City section of AIME in May, 1955.

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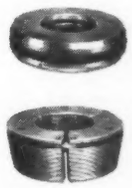

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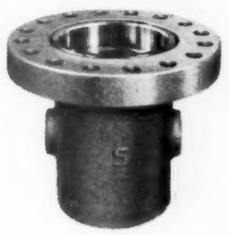
TYPE "S" HEAD



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New Approach for the . . .

Economic Design Of 440-Volt Lease Distribution Systems

About one-third of the total cost of lease electrification is represented by the motor and starter mechanism. This is a neat installation which utilizes a 15-hp motor and underground wiring to the distribution line pole.

Primary considerations given size and type transformers, use of capacitors, size of conductors

Glenn W. Webb
Application Engineer,
General Electric Company,
Dallas, Texas

EXCLUSIVE

COST of the first year's losses in a conventional oil field distribution system easily may amount to as much as 15 per cent of the distribution system costs. It is obvious that these losses should be carefully evaluated in designing such a distribution system. The period of time used in this evaluation will depend upon local circumstances, but a period of three years is considered average. When the distribution system design problem is approached on this basis, here are some general conclusions:

1. It is more economical to use a larger number of smaller-size transformers located closer to the wells to minimize secondary costs and losses. Thirty and 45-KVA self-protected, 3-phase transformers are the most economical choices for a majority of cases.
2. Capacitors are usually justified with the motors. Savings in transformer investment, secondary conductors and losses often will pay for the capacitors in less than two years. Presence of a power factor clause in a utility contract provides additional savings.
3. Conductor sizes should be selected on the basis of losses as well as voltage drops. The next larger size should be used if the reduction in line losses will pay for the additional cost in a reasonable time.

A system designed on these principles also offers operating advantages. Secondary line length and consequently direct lightning exposure to motors and starters is reduced. Voltage levels at the motors are generally raised, resulting in higher torques and efficiencies. Such a system is ideal for expansion, since no transformer capacity need be provided initially for unpredictable future loads. Transformer investment can be deferred until loads appear; then, transformers can be installed close to these loads for maximum efficiency. The application of these general principles will result in optimum overall economy and provide a bonus of operating advantages for most oil field distribution systems.

Flexibility and Reliability

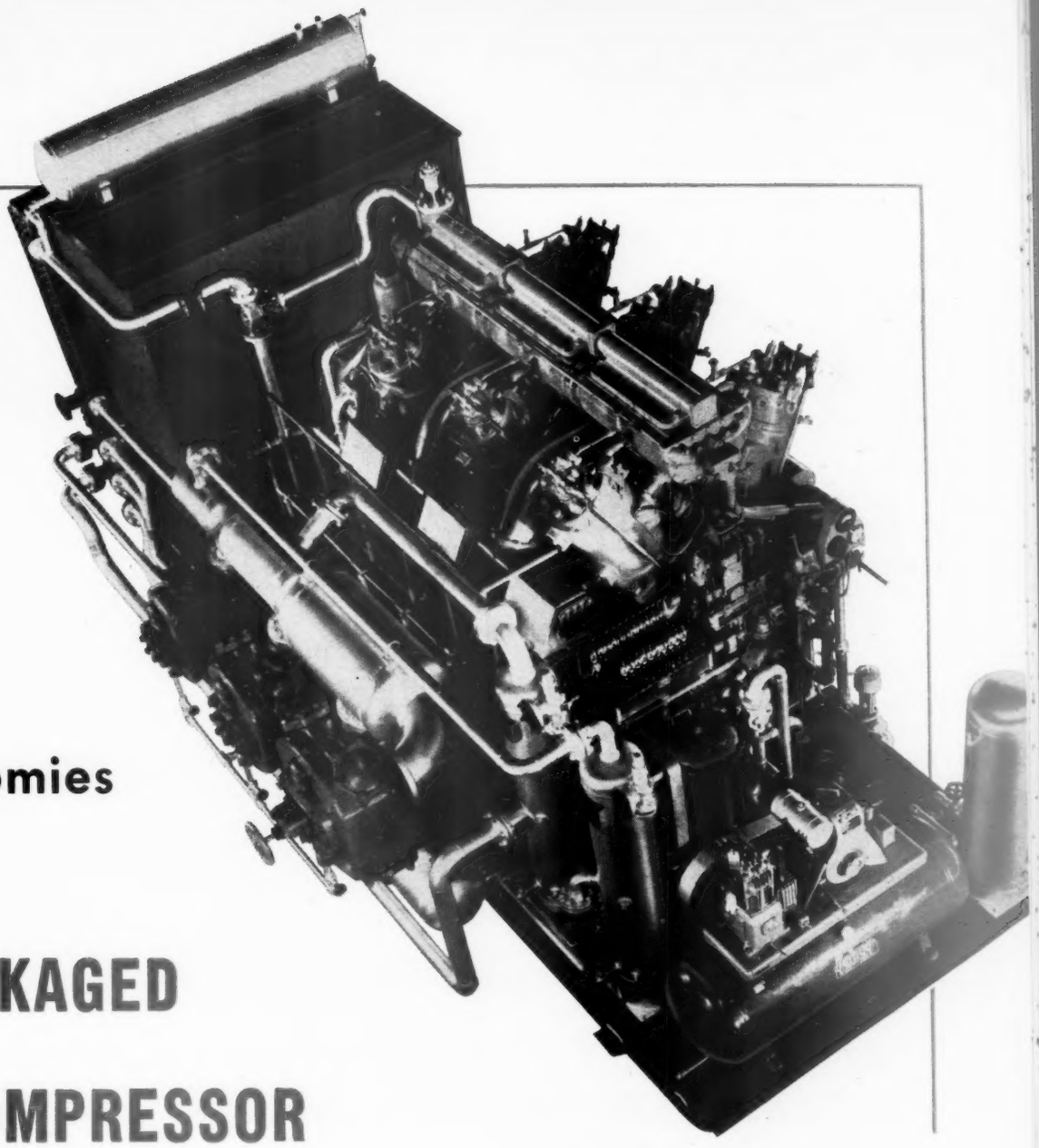
In recent years, the overall economy and reliability of electric powered pumping and the increased availability of electric power have accelerated the trend to electrification in the oil fields. About two-thirds of the cost of such electrification is represented by the power distribution system. One-third is represented by the motor and starter, the cost of which is fixed for a given well.

Basic Assumptions

The starting point in designing a distribution system is a scale map showing well locations and the point at which utility power is supplied, normally at the edge or corner of the lease. The motor horsepower rating required at each well is also known or can be calculated.

It is obvious that the lease configuration and distribution of loads will have a dominant influence on the power sys-

Another Example of Efficient Power at Lower Cost



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tem design. From an infinite number of possible configurations, one square mile containing 16 wells on uniform 40-acre spacing has been chosen as a basis for certain calculations, but the conclusions reached can be applied to many other configurations. Spot checks were calculated for a lease measuring 2 miles by ½ mile without effecting the general conclusions.

Voltages

The primary voltage will usually be determined by existing electric utility service voltages in the area. These are generally in the 12,470 to 13,800-volt range. Secondary or utilization voltages of 1100, 880, 762, and 440 volts (corresponding to 1200, 960, 832 and 480-volt distribution system levels) have been used. However, secondary equipment such as motors, starters, transformers; lightning arresters, capacitors, wire, and cable have not been generally standardized by the electrical manufacturers at voltage ratings between the 600 and 2400-volt levels.

Transformer Selection—Size

Once the primary- and secondary-voltage levels are decided, the next and most important step in the design of a distribution system is the selection of the transformer ratings and locations. The relation between transformer capacity and connected motor nameplate horsepower may be influenced by the following factors:

a. Presence or absence of properly sized capacitors at the individuals motors

b. Relation of nameplate horsepower to actual pumping loads. This is a function of the manner in which motor ratings are originally chosen, and of subsequent changes in the well.

c. Number of motors per transformer. Obviously, with three or more simultaneously operating motors per transformer, there will be diversity between individual motor peaks which tends to reduce the combined RMS load.

d. Pumping program, or hours per day running time for the motors involved

e. Ambient temperature conditions which vary with climate

f. Voltage conditions during starting and running for the most distant motor

These factors should be evaluated for any particular transformer installation. However, the following ground rules represent very conservative practice and were used in the economic comparisons which follow. These rules will generally insure ample transformer capacity and adequate motor voltages under the worst conditions:

1. Provide one KVA of transformer capacity per motor nameplate horsepower when capacitors are not used with the motors.
2. Provide 0.75 KVA of transformer capacity per motor nameplate when properly sized capacitors are used with the motors.
3. The minimum motor voltage during starting should not be less than 80 per cent of nameplate rating, which is 352 volts.
4. The voltage at the motor while running should be between 420 and 480 volts.

National Electrical Manufacturers Association standards specify that motors shall operate successfully with applied voltages within 10 per cent of rated value. However, successful operation is not necessarily most desirable operation. Excessively low voltage causes increased current and motor heating under loaded conditions, while excessively high voltage causes increased current and heating under no load or light load conditions. Since the motor is alternately heavily and lightly loaded during each pumping cycle it is obviously desirable to maintain the applied voltage as near rated value as possible.

In selecting the optimum economic size of transformers for a given lease, it is obvious that as the banks are in-

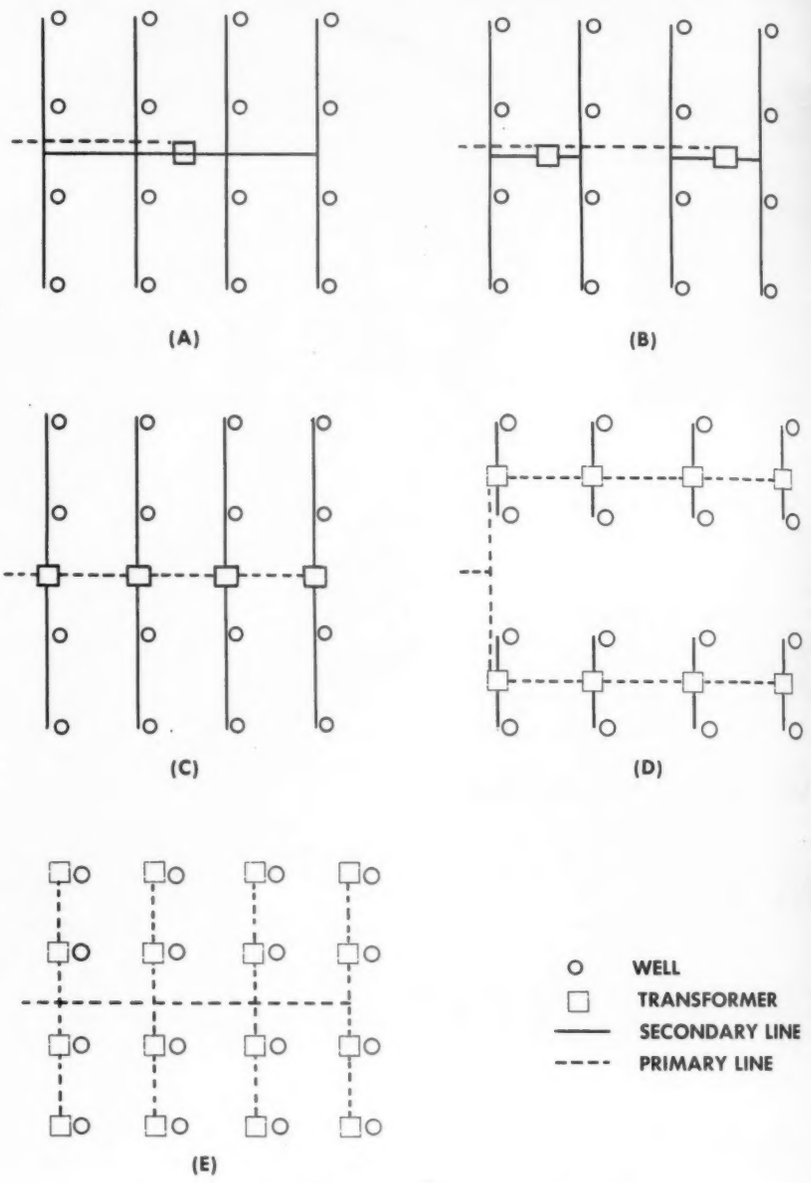

FIG. 1. Five methods of designing distribution systems for a sample lease of one square mile, containing 16 pumping wells on 40-acre spacing and 1320 ft apart.

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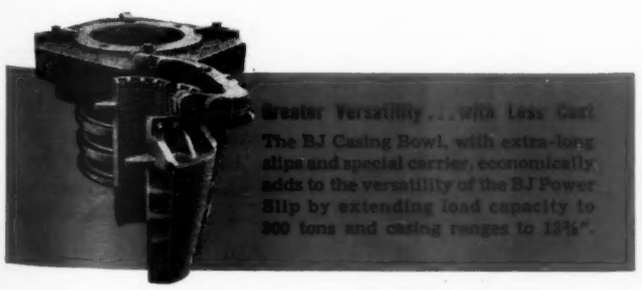

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creased in rating they must serve a larger area, increasing the cost of the secondary lines and losses. Also, voltage limitations stated above dictate that secondary lines cannot become unduly long. On the other hand, as individual transformer ratings become smaller, they cost more per KVA. When the ultimate of one transformer at each motor is reached, the secondary costs and losses disappear. But, transformer and primary costs are high. Between these two extremes lies the economic selection.

In order to determine this economic selection it is necessary to consider both initial system cost and operating cost. The major item of difference in the operating cost of various distribution systems is the cost of the I^2R losses in primary lines, transformers, and secondary lines. The value of these losses must be added to the cost of each alternative. In the following examples, a period of three years is used in capitalizing costs. This is believed to be in accordance with investment policies in the industry.

Using the square mile lease with 16 wells, it was assumed, for example, that each well pumping motor would be 5-hp. Four distribution system layouts involving different transformer ratings were designed to serve these 16 motors. Each layout was made to conform to the rules for transformer capacity and voltage drop stated above. Capacitors were included where appropriate. For instance, the first layout included four 15-KVA transformers as in Fig. 1 (c) and 2-KVAR capacitor with each of the 16 motors. Another layout included two 45-KVA transformers as in Fig. 1 (b) and no capacitors.

The original installed cost of each distribution system and the annual cost of losses for each system were calculated. By capitalizing installed cost on a three-year basis and adding losses, an annual total cost figure was obtained for each alternative system. These cost points were plotted on Fig. 2 vertically above the respective transformer ratings involved. A line was drawn connecting the cost points of the four systems designed to serve the 5-hp wells. Similar lines were drawn through points representing distribution system costs for other well horsepower ratings up through 30 hp. Each point is marked with two numbers: The first indicating the number of transformers in that system; and, the second indicating the number of motors to which capacitors are applied.

It will be noted from Fig. 2 that for any motor rating from 5 to 30 hp, the lowest cost distribution system will include either 30 or 45-KVA transformers. It also will be noted that the

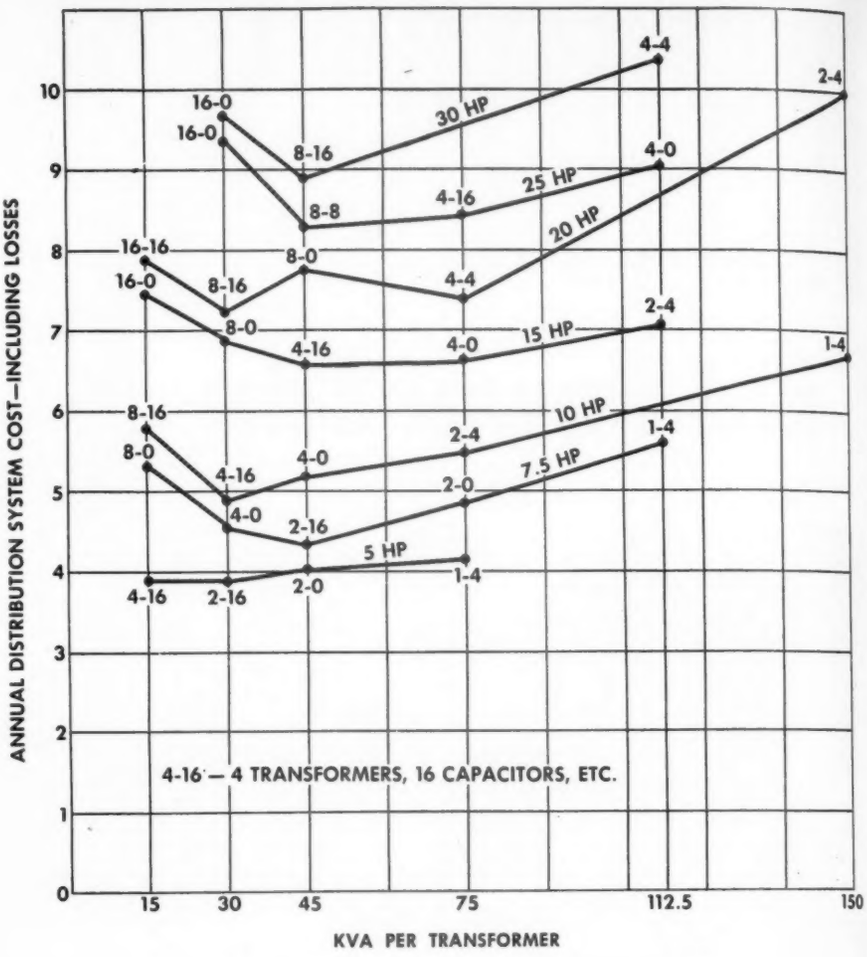


FIG. 2. Installed distribution system cost capitalized over three-year period plus losses are plotted against KVA per transformer for each alternative system.

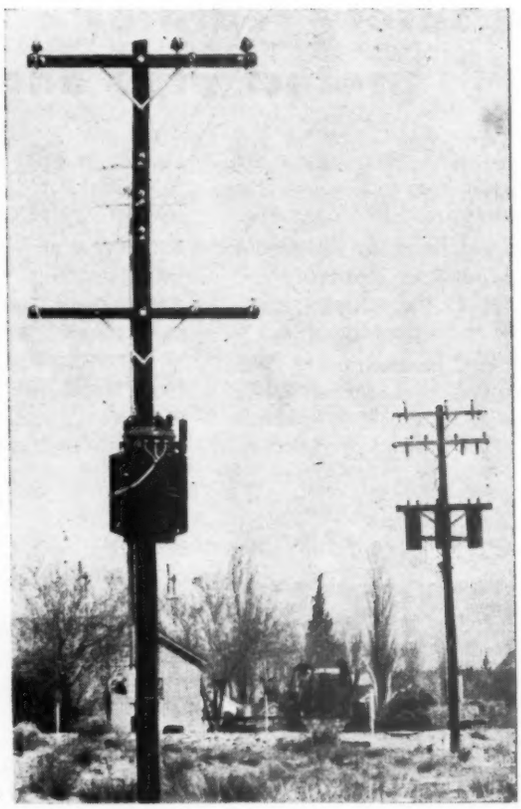
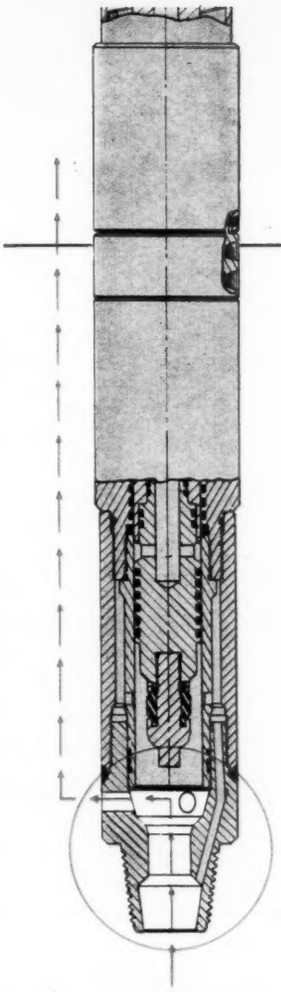


FIG. 3. Comparison of a three-phase 45-KVA transformer and a similar size single-phase bank of transformers. Savings to be made by the single unit are in cross arms, pole hardware, connections and installation labor.



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lowest cost distribution system almost invariably will incluude capacitors at every motor. Stated another way, these curves show that maximum economy is achieved when each transformer serves about 40 to 60 hp of oil well pumping motors. Also, oil field capacitors more than pay for themselves in reduced distribution system cost and reduced losses.

Although the above conclusions are based on a uniform 40-acre well spacing, it has been found that similar results are obtained when less uniform lease configurations are studied. For any actual well layout, a quick cost comparison between two or three transformer ratings will usually indicate the economic choice.

Transformer Selection—Type

Having determined the economic rating for the transformers, some consideration should be given to available transformer types. Traditionally, banks consisting of three single-phase units have been used in oil fields. The smaller sizes, up to about 25-KVA units, were hung from cross arms on a single pole. Larger sizes were mounted on platforms or on the ground. Lightning arresters and fused cutouts were mounted separately.

On the other hand, many utility companies use distribution transformers with self-contained lightning and over current protection. The self-protected units are used because of a saving in cost and because of superior transformer protection. Three-phase, self-protected transformers are available for oil field application. These transformers have delta-delta or wye-delta connections with primary taps; valve-type lightning arrestors mounted on the tank; internal high-voltage fuses; three-pole, low-voltage circuit breaker; external breaker operating handle; signal light, and overload reset device. The lightning arresters mounted on the tank offer the closest possible protection to the windings. Connections between phases are inside the tank and not exposed to the hazards of weather and foreign objects. The red signal light gives warning of moderate overloads, and the secondary breaker protects against secondary short circuits or excessive overloads, which would cause exorbitant insulation deterioration. Primary fuses provide normal protection against internal short circuits.

Three-phase, self-protected transformers in the 30- and 45-KVA ratings are less expensive than three single-phase units of the same bank rating plus separate fused cutouts and arresters. And of course, the single phase bank would not include the secondary circuit breaker, signal light, reset device, etc., which provide coordinated

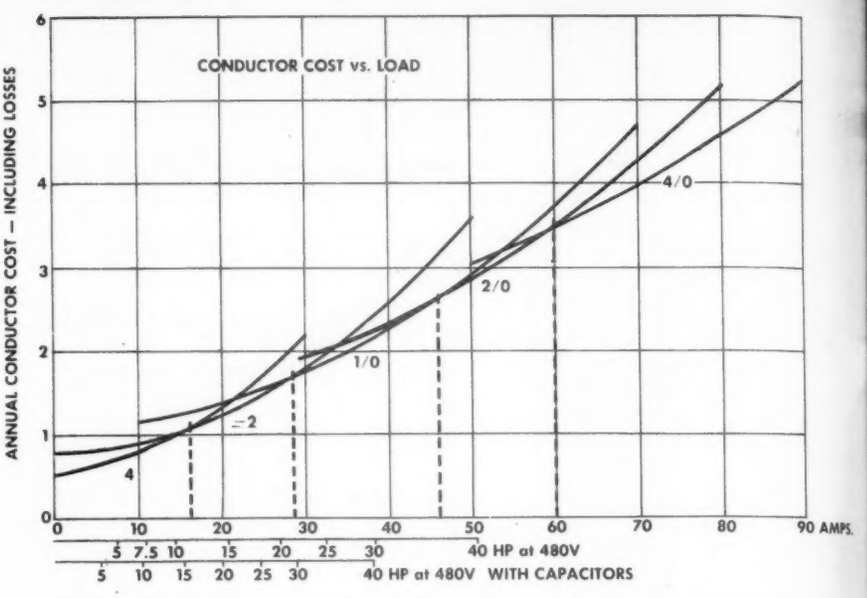
CONDUCTOR COST vs. LOAD
ANNUAL CONDUCTOR COST — INCLUDING LOSSES
4/0
2/0
1/0
2
4
0 10 20 30 40 50 60 70 80 90 AMPS.
5 7.5 10 15 20 25 30 40 HP at 480V
5 10 15 20 25 30 40 HP at 480V WITH CAPACITORS

FIG. 4. Family of curves for five standard ACSR conductor sizes. These curves plot the capitalized cost on a three-year basis for a unit length of 3-phase line including wire cost, installation and losses versus RMS current.

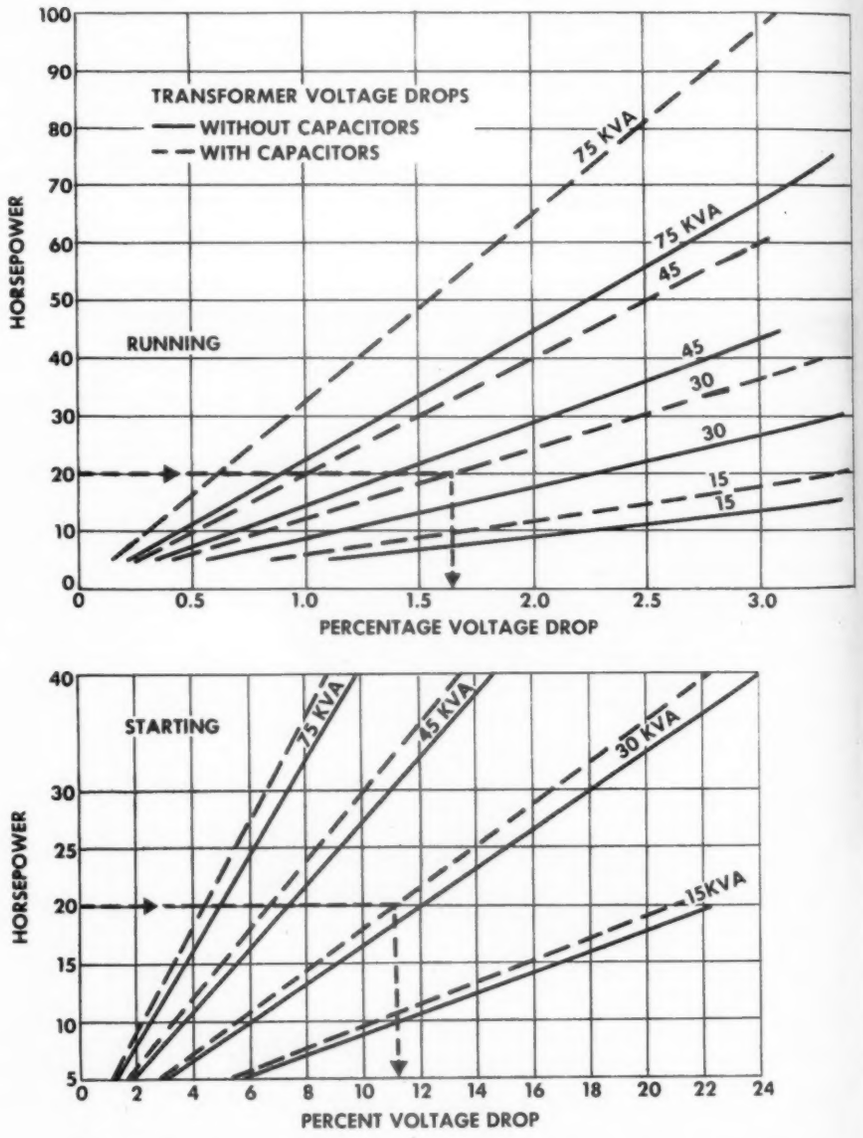

FIG. 5. Percentage voltage drop in the transformers versus load (horsepower) for various KVA ratings.

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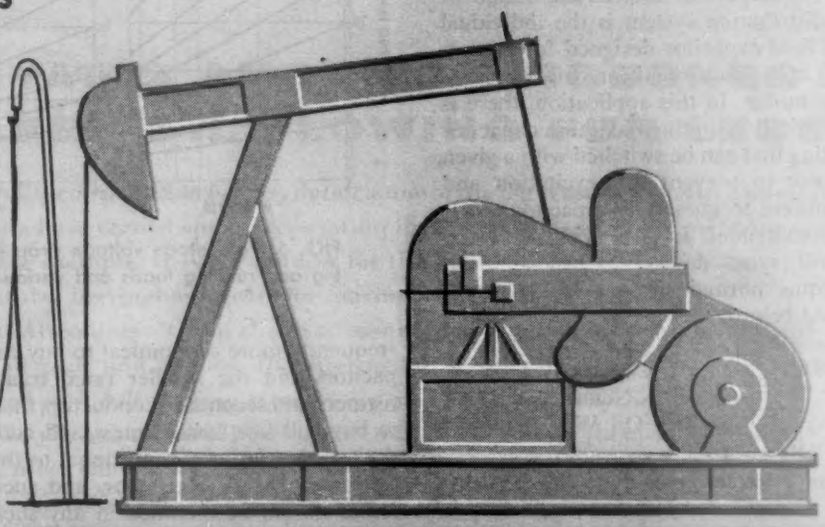

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overload protection for the 3-phase unit. Fig. 3 shows a 3-phase 45-KVA installation in the foreground with a similar-sized, single-phase bank in the background. It is obvious that the savings in cross arms, pole hardware, connections and installation labor would further favor the 3-phase self-protected units.

Banks of single-phase transformers have traditionally been connected delta-delta, which avoids the necessity of a third overload in the motor starter for primary single-phase protection. In the 3-phase transformer, the choice between delta-delta or wye-delta plus a third overload per starter is a question of economics. At present prices, the latter arrangement is usually less expensive.

In the single-phase, delta-delta bank, the open delta connection can carry 58 per cent of the former bank load in case of the failure of one unit. Considering recent years' advances in transformer design and the superior lightning and overload protection provided in the self-protected units, this provision for transformer failure is no longer a practical consideration in system design. Three-phase, self-protected transformers are being used in oil field applications. The econimic and engineering facts support considerable extension of their use in the future.

Capacitors

An important tool in the design of a distribution system is the individual oil field capacitor designed for mounting at the motor and for switching with the motor. In this application, there is a limitation on the maximum capacitor rating that can be switched with a given motor to prevent self excitation and transient torques. The capacitor rating recommended for use with the usual 1200 rpm, drip-proof, high-starting torque, normal-slip motors are tabulated below:

Recommended Capacitor Ratings for Switching with Nema Design C, Open, 1200 RPM, Oil Well Pumping Motors.

Motor Horsepower	Capacitor KVAR
5	2
7.5	3
10	4
15	5
20	6
25	8
30	9
40	12

The beam pumping load is a cyclic load peaking twice per cycle, once when the rod string is lifted and again when the counterweight is lifted. During these peaks the motor carries greater than rated load and between peaks it is lightly loaded. The power factor, of course, varies widely as the load varies, perhaps 20 to 50 times per minute. The use of capacitors improves this variable power factor and results in a decrease in the variable line current. Various studies and tests have been made which indicate a reduction in RMS line currents of 20 to 40 per cent by adding the proper capacitors. The RMS or "root mean square" current can be defined as a constant value of current which would have the same heating or loss effect as the actual fluctuating current.

This reduction in current means that when the capacitors are used the current capacity of the distribution system can be reduced by 20 to 40 per cent. Depending on the relative motor and transformer sizes involved, it is frequently more economical to buy capacitors and use smaller rated transformers and secondary conductors than to buy full-size transformers and conductors. Losses are proportional to the square of the power factor, and such losses should be included in any such cost comparison.

Assuming that secondary conductor size and length remains constant and assuming a conservative 25 per cent reduction in current, the addition of capacitors has the following general effect:

a) A 25 per cent reduction in transformer investment
b) A 44 per cent reduction in the cost of secondary losses
c) Direct saving in power bills if a power factor clause is involved and enforced
d) An approximate 25 per cent reduction in secondary voltage drop due to reduced current

Actually, the addition of capacitors might result in a change in the size or length of secondary conductors to obtain the best overall design, but it is still true that the most economical overall system, in most cases, will include capacitors with the motors. For example, on the 20-hp motor curve of Fig. 2, a system with eight 30-KVA transformers plus a 6-KVAR capacitor with each motor is about 5 per cent less expensive than one with eight 45-KVA transformers and no capacitors. Similar comparsions are apparent on most of the curves.

Conductor Sizes

Having determined transformer sizes and locations and where capacitors are to be used with the motors, it is a relatively simple matter to select optimum conductor sizes. Fig. 4 is a family of curves for five standard, normally stocked ACSR conductor sizes. These curves plot the capitalized cost on a three-year basis for a unit length of 3-phase line including wire cost, installation cost, and losses, versus RMS current. Pole and hardware costs are not included. Loss values are calculated for 8760 hours at one cent per KW-HR. The curves vary as the square of current and if extended would intersect the vertical scale (zero current) at a point corresponding to the capitalized initial installed cost. They are calculated from the following formula:

$$T = C + 3I^2RHE/1000$$

where

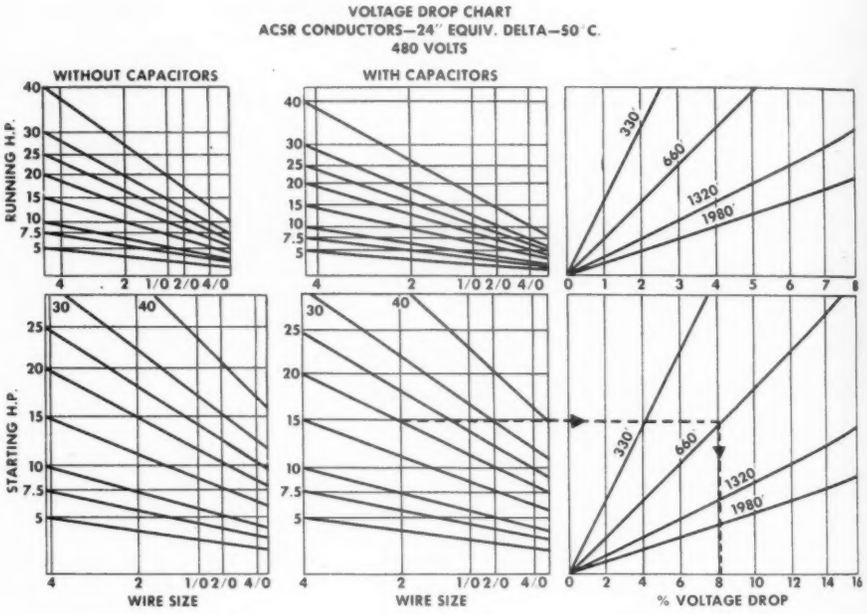
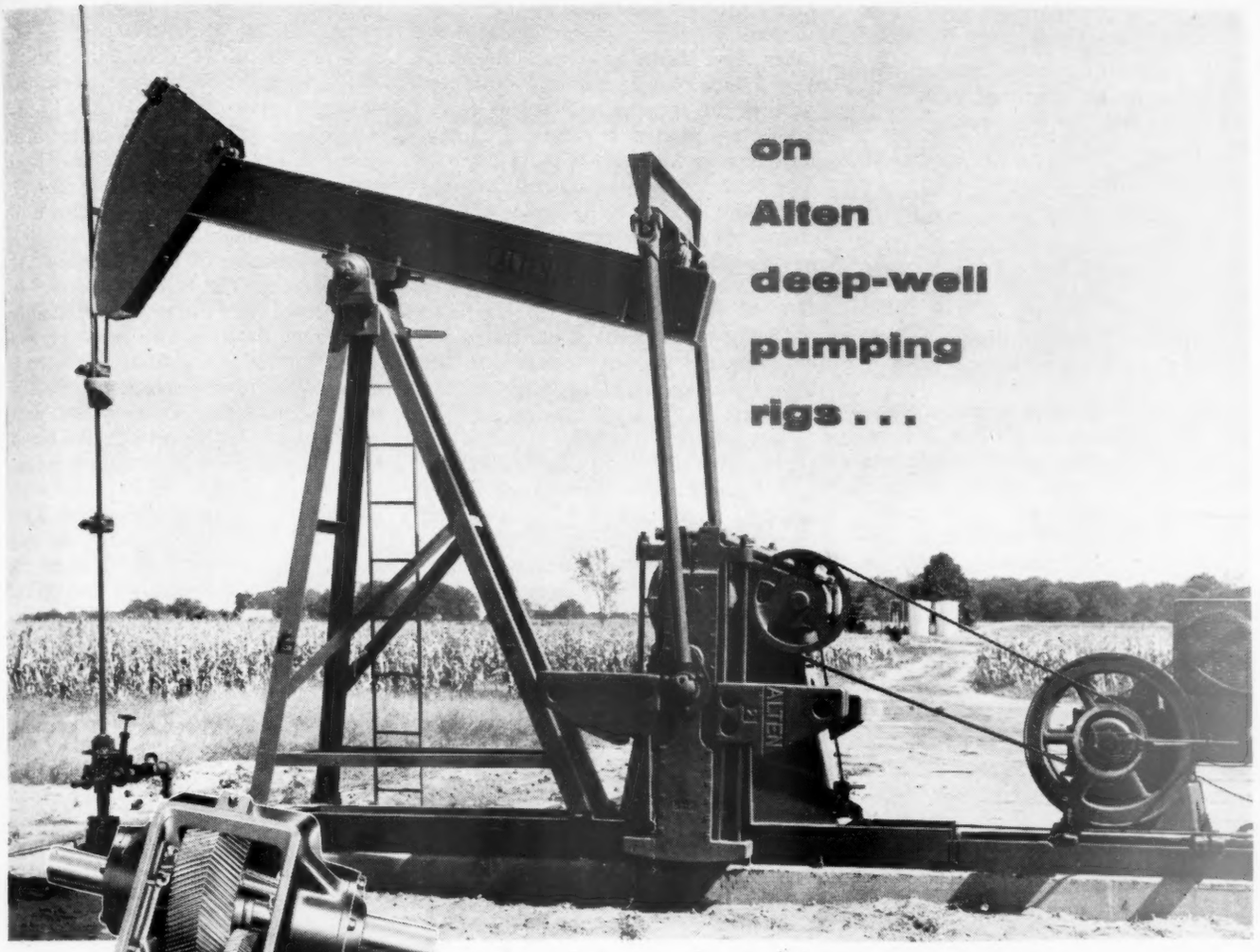
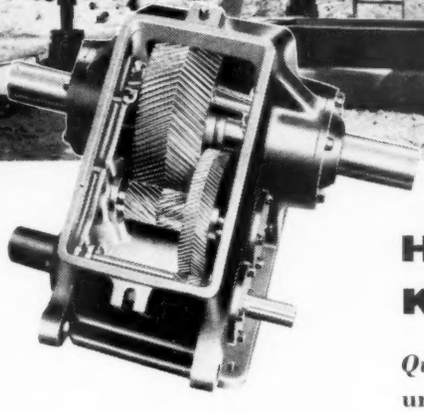


FIG. 6. Percentage voltage drop in secondary conductors for various starting and running loads and various wire sizes.





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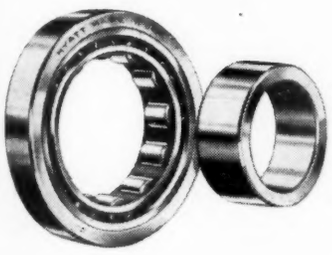

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T = total annual cost per unit length plotted as the ordinate

C = capitalized initial installed cost of a unit length of three conductors

I = RMS load amperes plotted as the abscissa

R = resistance of a unit length of one conductor in ohms

H = Hours of operation on which annual cost of losses is based

E = average cost of energy in dollars per kilowatt hour

The unit length can be any convenient distance such as 1000 ft, a span, or a mile. For convenience in selecting sizes off the curves, some additional horizontal scales have been added which convert RMS amperes to approximate motor horsepower with, or without, capacitors. Similar curves could be plotted using actual values for conductor, installation, and power costs which would apply to any particular lease or area.

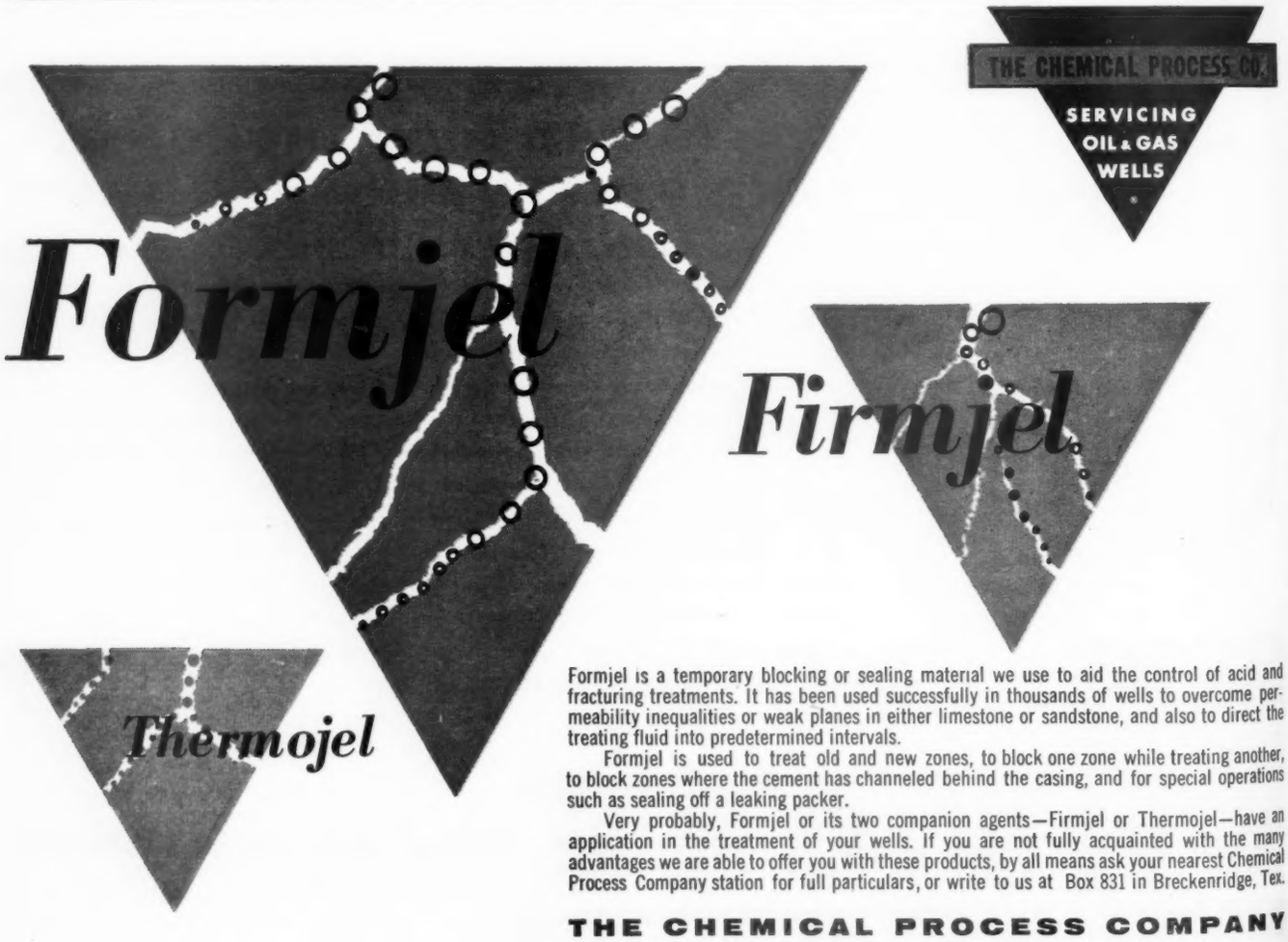
Voltage Drop

One other important check must be made before the conductor size selections are final. This is the check of starting and running voltages at the motor which is farthest from the transformer. To facilitate this check, two other curve sheets have been prepared. Fig. 5 is a plot of per cent—voltage drop in the transformers versus load. Loads are plotted in terms of motor horsepower, with and without capacitors, both for the starting and running condition. Fig. 6 is a similar set of curves showing per cent-voltage drops in secondary conductors.

Use of Charts

Use of these charts is illustrated by checking the starting voltage for the lowest point on the 20-hp curve of Fig. 2. This is the 8-transformer layout Fig. 1 (d). Each 30-KVA transformer serves two 20-hp motors with 6-KVAR capacitors at each motor. There are 660 ft of secondary between the transformer and each motor. From Fig. 4, the economical secondary wire size for a 20-hp load with capacitors is No. 2. From the curves of Fig. 5, the transformer voltage drop for one running motor is 1.65 per cent, and for the starting motor is 11.2 per cent. The secondary line drop for the starting motor from Fig. 6 is 8.15 per cent. The arithmetic sum of these drops is 21 per cent. This percentage is based on the no load secondary voltage of 480 volts, which should be attainable by proper transformer tap settings. Resulting voltage at the motor is 79 per cent of 480 or 379 volts. Since this is 86 per cent of the motor nameplate voltage, it is acceptable. Had the starting voltage on the farthest motor been less than 352 volts, it would have been necessary to increase the wire size.

The drop in the primary lines ordinarily is so small as to be an insignificant percentage of the total, and can be neglected. The error introduced by arithmetic, rather than vector addition of voltage drops is also small enough to be ignored. In plotting the voltage drop and wire size selection curves, it was assumed that motors would be so selected that RMS load currents would be equal to nameplate ratings. It is realized that actual practice in motor selection may result in motors whose RMS loads are below their ratings. In such cases, the answers derived from the curves will be conservative and on the safe side. It was also assumed that average uncorrected power factor for beam-pumping motors is 60 per cent running and 40 per cent starting. Capacitors were assumed to reduce the RMS load amperes by 25 per cent for running and 5 per cent for starting, with improvements in average power factor to 90 per cent and 42 per cent respectively. * * *



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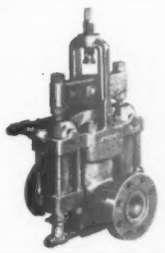

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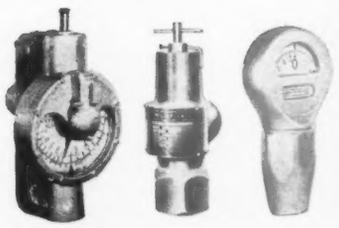

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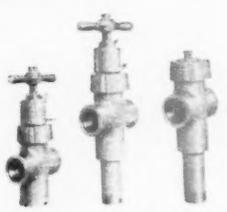

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Bateman Drilling Company's Newest Barge Equipped with . . .

Packaged Diesel-Electric Power Plant

New System Features Skid-Mounted Units, Simplified Controls, Assembly-Line-Made Components, Flexibility, and Competitive Price

FIG. 1. Bateman Drilling Company's newest barge, "The Henry Bell," in the final stages of construction at Hunt Tool Company yards at Harvey, Louisiana.

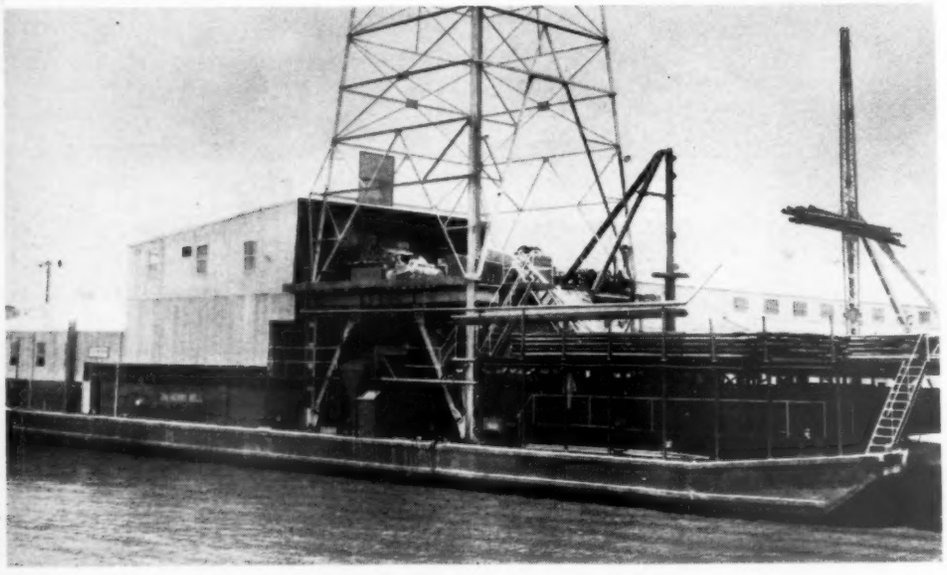
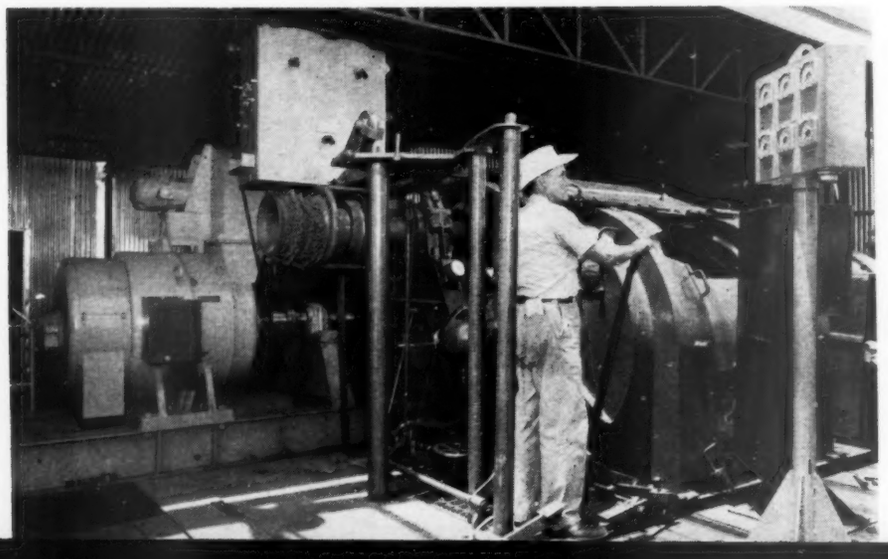


FIG. 2. Toolpusher C. S. "Scotty" Scott inspects driller's instrument panel while standing at the drawworks. From this position, the driller controls the entire power plant.



BATEMAN Drilling Company of New Orleans, Louisiana, recently christened its newest drilling barge, "The Henry Bell," said to be the first barge rig equipped with Alco Products, Incorporated's new standard diesel-electric packaged power plant. Primary power is provided by two diesel engines, each skid-mounted with two main generators plus an auxiliary for lighting and other power requirements. The complete power package includes two drawworks motors, two mud pump motors, and control equipment. The controls include one compact equipment cabinet, a control console mounted above and behind the driller's position on the rig floor, and an instrument panel.

Barge Rig Specifications

The barge is 180 ft in length and 40 ft wide, has a depth of 10 ft 8 in., and draws 4½ ft when fully loaded. It is equipped with a steam-type drawworks and two 625-hp, 7¾-in. by 16-in. mud pumps. Derrick substructure has a capacity of 1,650,000 lb, and the derrick has a 900,000-lb capacity and a height of 136 ft. The barge is equipped with a 450-ton capacity crown block, a 350-ton capacity hook and traveling block and will handle 1¼-in. drilling line.

The barge contains a fully equipped galley and sleeping accommodations for a full drilling crew. Storage space is provided for 1100 bbl of drilling mud, 47,000 gal of diesel fuel oil, and 4000 sacks of bulk mud. The rig is capable of drilling to 15,000 ft with 4½-in. drill pipe.

XUM

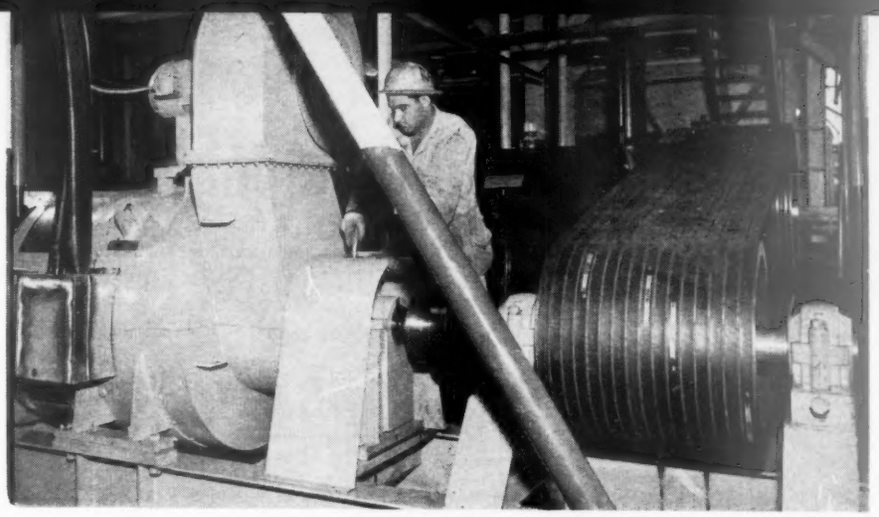


FIG. 3. One of the two skid-mounted mud pump motors is shown at left, with motor blower unit mounted on top. Vee belts, right, connect to 625-hp mud pump.

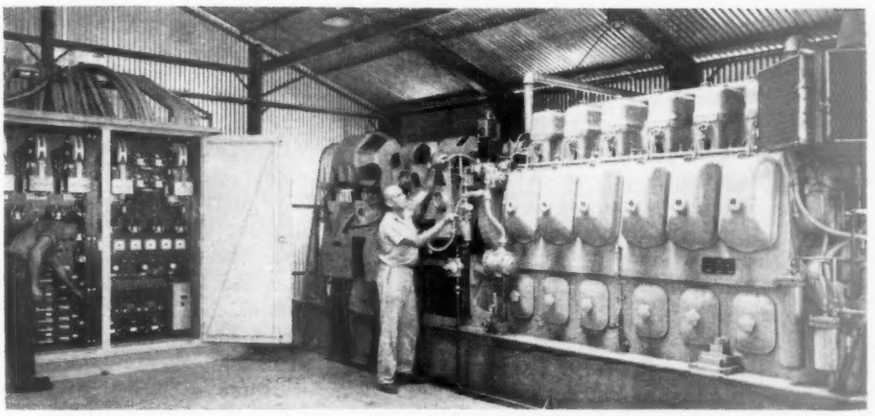
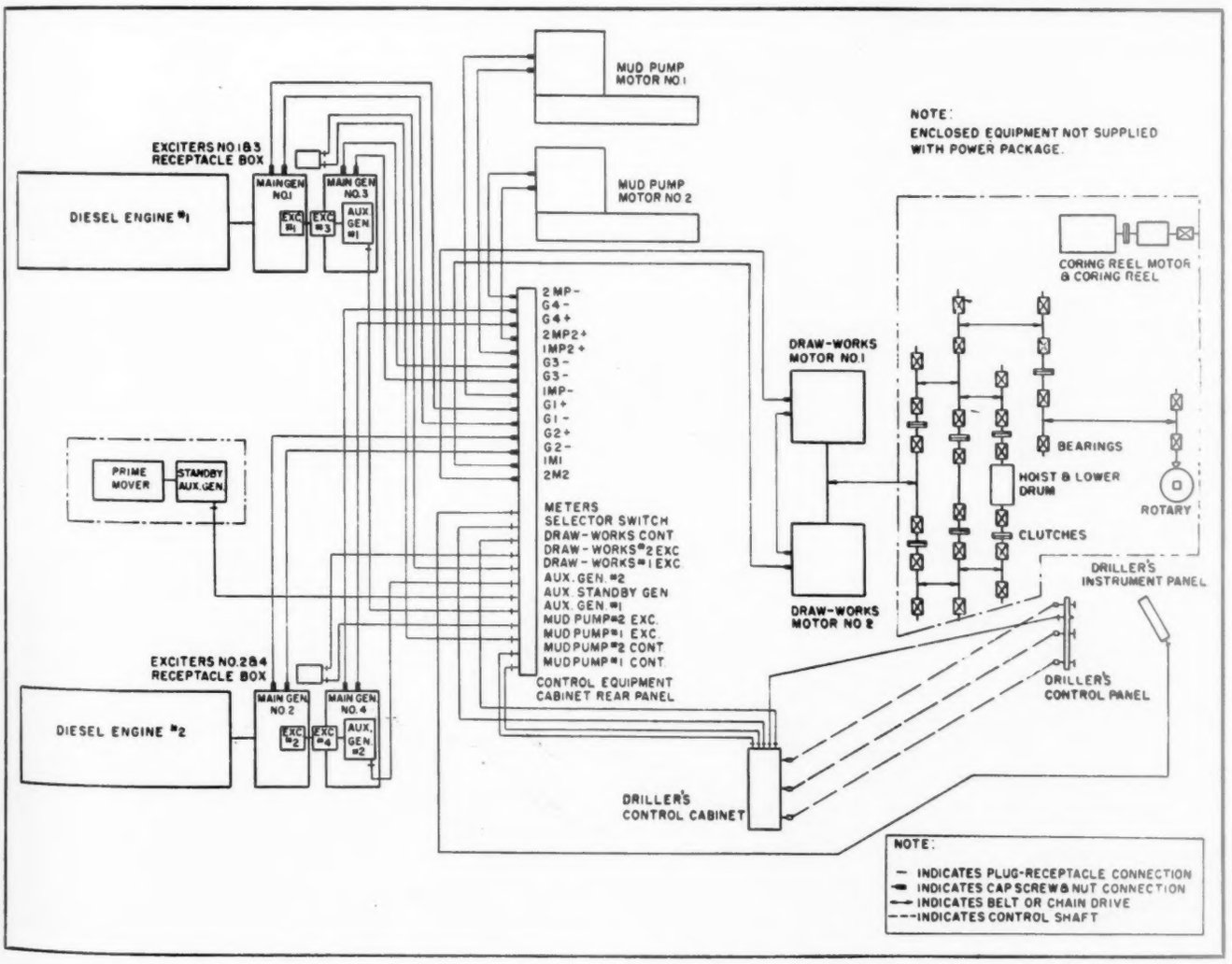


FIG. 4. Primary power is furnished by two 800-hp diesel engines, each skid-mounted with two main generators, plus an auxiliary for lighting and other power requirements. Main control equipment is in one compact cabinet shown at left.

FIG. 5. Schematic wiring diagram of the packaged Alco diesel-electric power plant illustrates the flexibility of operation of all components.



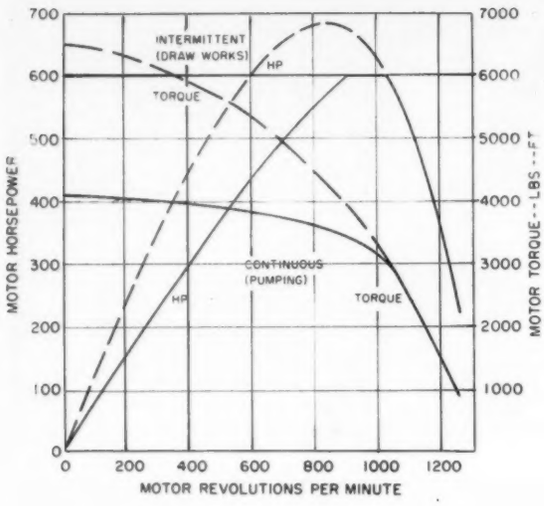


FIG. 6. Torque and horsepower characteristics of the diesel-electric drawworks drive over a range from 0 to 1200 rpm. One unit alone provides full torque in emergencies.

Power Plant

Power for the rig is furnished by two 800-hp, 6-cylinder, 4-cycle diesel engines equipped with turbosuperchargers. The fuel system consists of an engine mounted fuel booster pump, which provides a constant supply of filtered fuel to the injection pumps. The lubricating system is a full-pressure type integral with the engine. It is equipped with an automatic audible and visible alarm to indicate low oil pressure and high water temperature. Cooling water is circulated through the engine and lubricating oil cooler by a gear-driven centrifugal pump, and the engines have been adapted to cooling by a specially designed heat exchanger. An air motor that operates on a maximum air pressure of 150 psi is provided for engine starting.

A 500-kw, 250-volt differential field generator for one mud pump motor and a similar generator of 400-kw, 250-volt capacity for one drawworks motor are mounted on a common skid with each diesel engine. Each generator can be operated singly or in combination from the driller's control console. In an emergency, the entire rig can be powered from either main generator set.

Two 50-kw, 125-volt dc auxiliary generatotrs, belt driven from the main generator shaft, are mounted on each engine set. They supply all auxiliary power for the entire rig.

Drawworks Drive

The drawworks drive assembly consists of two 500-hp, 600-rpm shunt-field motors, each equipped with a blower for ventilating and cooling. Maximum intermittent torque of the motors is 250 per cent of rated torque.

Mud Pump Motors

The two mud pump motors are shunt-field units, each capable of 600-hp at 600-rpm and equipped with motor driven blowers. Each unit is skid mounted. Shunt-field motors have an important safety advantage in that they automatically guard against the dangers of motor overspeed. They require only a simple, small reversing switch in the exciter field, can operate at full torque at one-half speed, and provide for stable speed and good control in catheading, hoisting, and making or breaking drill pipe joints.

Controls

The control cabinet contains the main power contactors, control relays, overload relays for protection of personnel and equipment, and the auxiliary power distribution panel. For ease of operation, all drilling controls are found on the driller's control console, including the rheostats for the exciters that regulate the speed of the main motors through generator voltage control, and the reversing switches, which contain 30 hoist and 15 lowering positions. The final item of equipment in the power package is the instrument panel, which contains the voltmeters and ammeters designed to indicate loading of the generators supplying power for the drawworks and mud pump motors.

Other than the major features on Bateman Drilling Company's new barge rig, "The Henry Bell," there are a number of interesting cost-saving ideas that are worthy of mention. Included here are five of these noted items that add to the efficient operation of this new barge rig.

Mud Suction Cut-off

A simple, positive shut-off has been incorporated in both mud pump suctions connected into the centralized

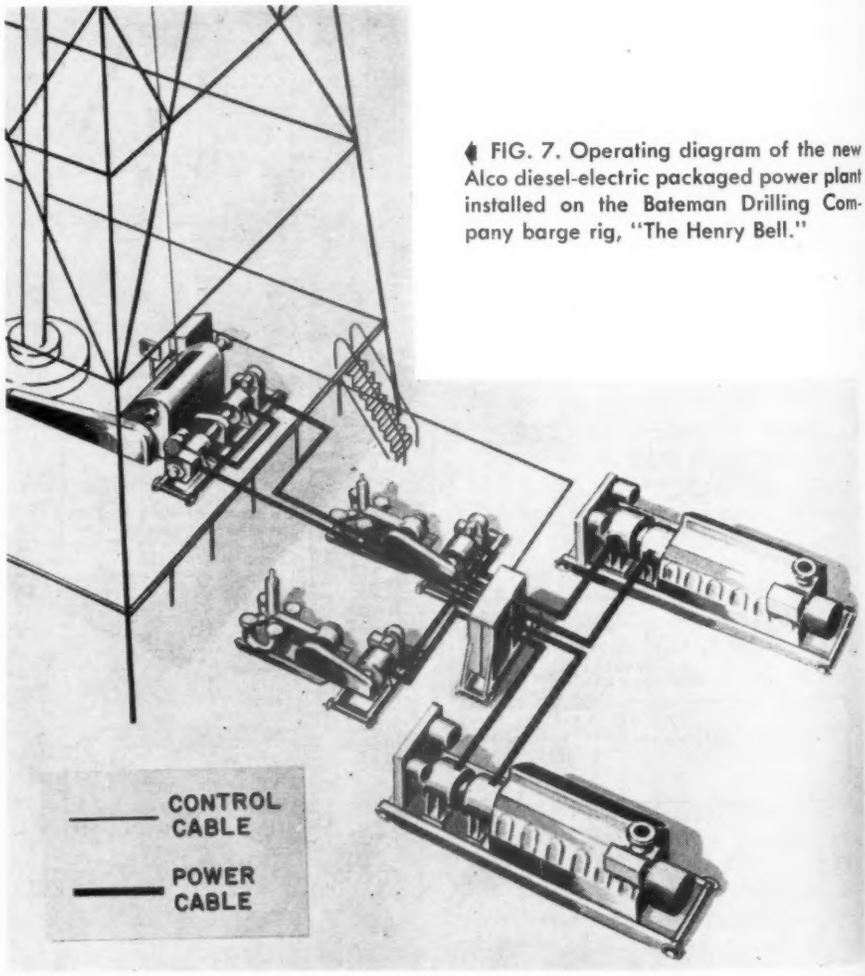


FIG. 7. Operating diagram of the new Alco diesel-electric packaged power plant installed on the Bateman Drilling Company barge rig, "The Henry Bell."

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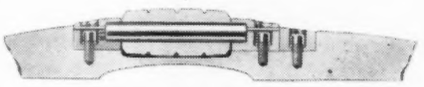

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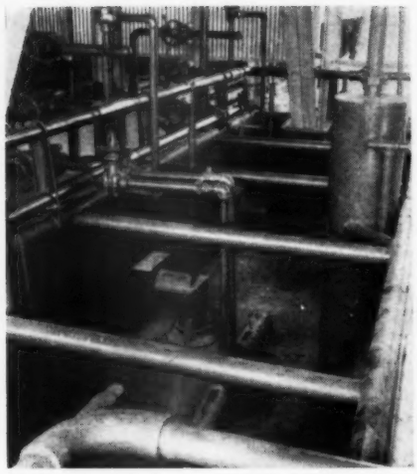

FIG. 8. Mud tank equipped with disc-type suction line valves.

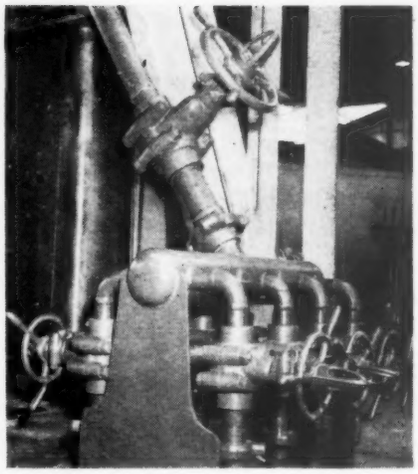

FIG. 11. Flow control manifold from pumps to handle water in hull compartments and mud storage beneath pipe rack.

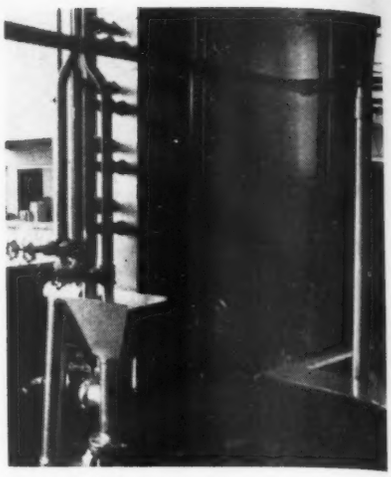

FIG. 12. Engine jacket water cooler incorporates three tube bundles.

FIG. 9. Mud agitation in bottom of tank is accomplished by these two jets.

FIG. 10. Large integrated lubricant storage tank handles four types of oils.

mud tank. Fig. 8 is a view of the empty mud tank that illustrates this unique suction shut-off idea. The open suction was supported several inches off the bottom of the tank as shown. Inside the vertical section of this suction line is a disc attached to a stem that extends up inside a section of telescoping pipe. The top nipple of this section is threaded so that the stem can be raised and lowered by turning the valve stem handle. It is a positive closing disc valve in that the small hydrostatic pressure at the bottom of the mud tank acts against the disc to help keep it sealed.

Mud Mixing Jets

To maintain an evenly mixed mud, two mud jets were installed on the bottom of the mud tank as shown in Fig. 9. Mud pumped through two 1½-in. lines provides the jetting action through horizontal discharges directed toward the ends of the tank. A venturi effect was achieved in the jets by enclosing the discharge nozzle at one end with a short section of 4-in. pipe. A slot was cut in the top of this housing just above the nozzle so that mud from above could be sucked into the jet, which was directed somewhat by the housing. These jets provided an even mixture of mud on the bottom of the tank where settling normally occurs.

Lubricant Storage

On the main deck just forward of the engine-generator room is the metal storage compartment (Fig. 10) for various type lubricants required on the barge rig. Ample storage for four different type oils is provided in this one large tank, which is supported off the barge deck at a convenient height. Gage glasses to each compartment indicate the quantity of chain oil, diesel oil, SAE 30 and SAE 50 lubricating oil. This lubricant storage is located behind the mud pumps on the main deck and is convenient to all points of use.

Storage Manifold

Located on the main deck near the mud tank "amid ship" is the manifold (Fig. 11), which controls the flow of mud and water from the pump discharge to storage compartments in the barge hull and into mud storage tanks underneath the pipe rack on the forward main deck. When it is necessary to sink the barge, water can be pumped into compartments in the barge hull or mud can be pumped into the storage tanks that support the pipe rack. Position of this manifold is located strategically so that information can be relayed to the operator of the manifold.

Jacket Water Cooler

Jacket water from two 800-hp diesel engines is cooled in a fabricated cooler shown in Fig. 12. It consists of a tall rectangular steel box inside of which have been placed three tube bundles. Inlet and outlet connections are provided on the outside of the cooler body for each tube bundle. Water can be pumped through any or all the tube bundles, depending upon the operating conditions of the engines. When only one engine is in use, it may be necessary only to use one tube bundle. During deep drilling operations when both engines are in service, all three bundles may be needed. Valves on the discharge lines from the tube bundles permit this control. The cooler is located aft on the barge at the rear end of the engine-generator room. Engine water enters the rectangular tank at the lower end through one 3-in. connection and flows back to the engines through a second 3-in. line also connected to the lower end of the tank. * * *

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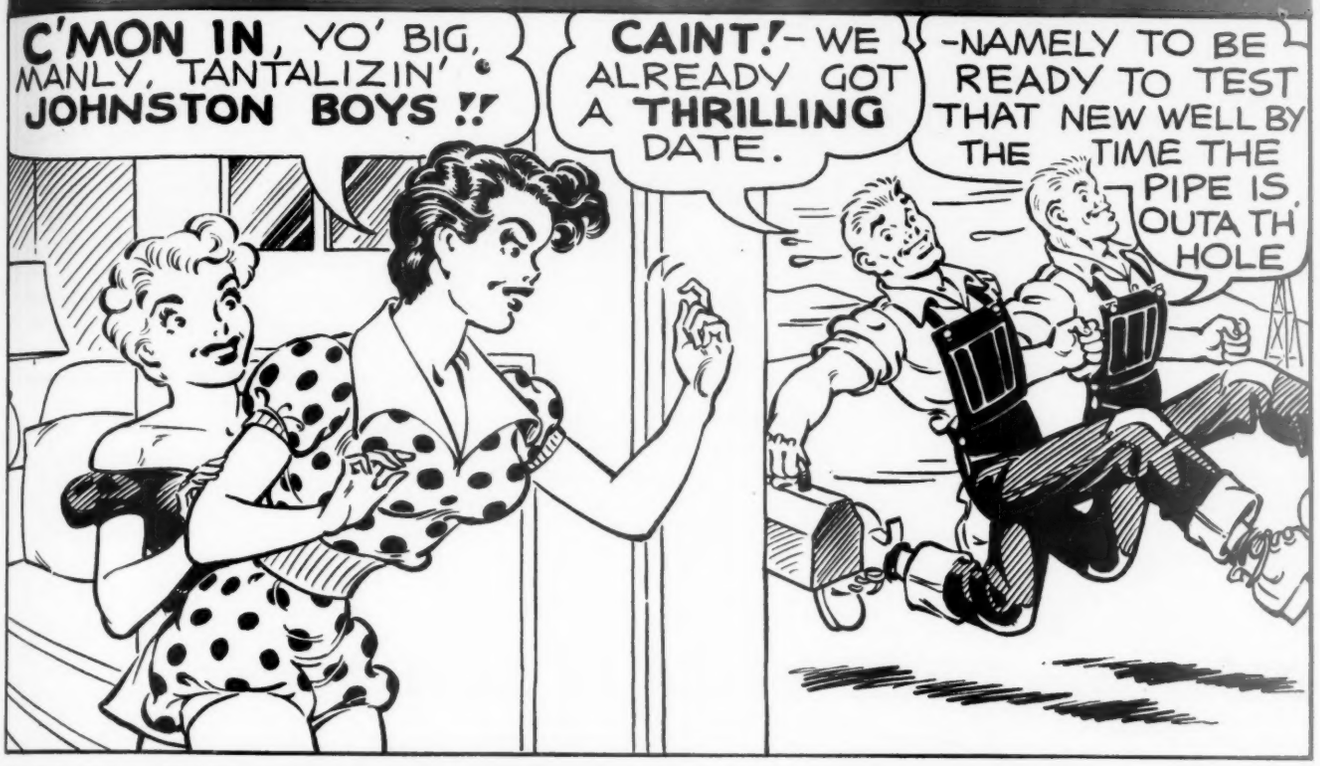
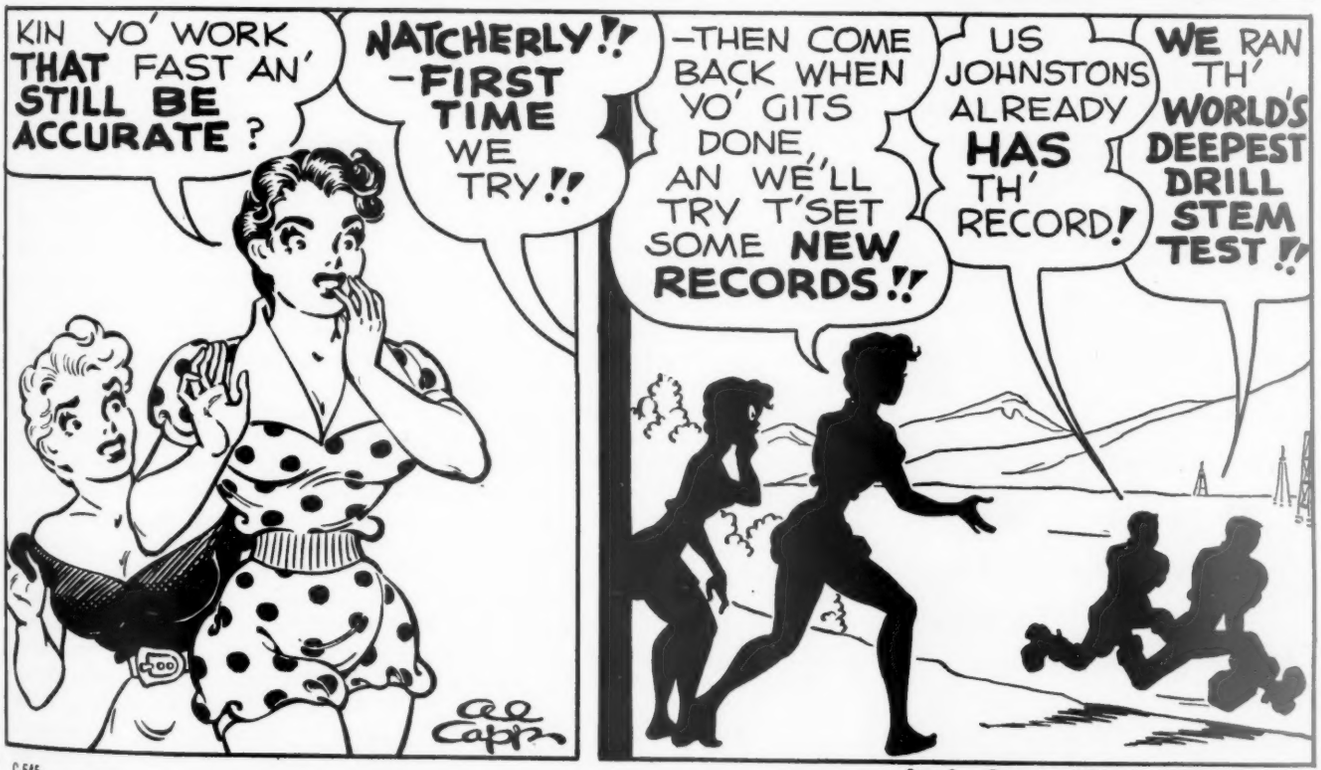

C'MON IN, YO' BIG, MANLY, TANTALIZIN' JOHNSTON BOYS !!
CAINT!- WE ALREADY GOT A THRILLING DATE.
-NAMELY TO BE READY TO TEST THAT NEW WELL BY THE TIME THE PIPE IS OUTA TH' HOLE


KIN YO' WORK THAT FAST AN' STILL BE ACCURATE ?
NATCHERLY!! -FIRST TIME WE TRY!!
-THEN COME BACK WHEN YO' GITS DONE, AN WE'LL TRY T'SET SOME NEW RECORDS!!
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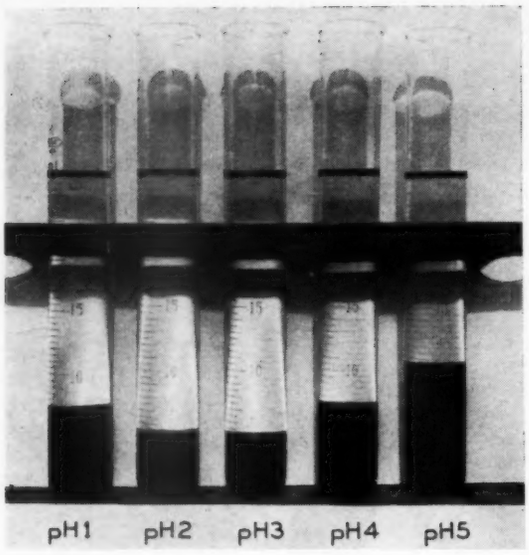


FIG. 1. Silicate swelling varies as the pH of the spent acid as demonstrated above for an equal starting volume of silicate. Clay mineral used consisted of 50 per cent illite, 20 per cent amorphous silicate and 30 per cent feldspar-quartz.

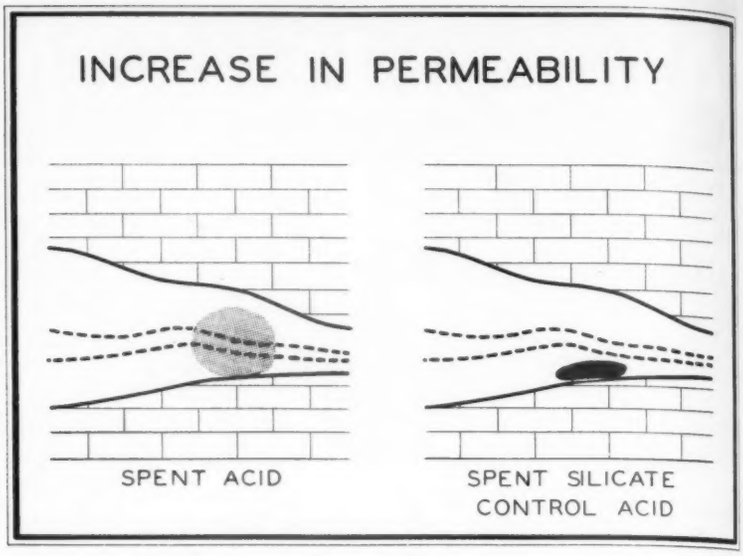


FIG. 2. By controlling the swelling of silicate particles, permeability loss is minimized, and such particles may be flushed back into the well bore after the acid has freed them from the limestone.

Acidizing Deep Wells in East Texas

Paul Clinkenbeard

New additive controls pH of spent acid to minimize silicate swelling

EXCLUSIVE

MUCH of the research to increase the scope and value of acidizing has been devoted to three important problems: (1) How to increase the penetration of hydrochloric acid into the formation, (2) how to prevent a blockage of permeability caused by swelling of silicate particles dislodged by the acid treatment, and (3) how to extend the benefits of the acid over a greater vertical section of the pay.

Many types of acids and chemicals have been tested in an attempt to solve the first problem, that of increasing the penetration of acid. The introduction of gelled acid was a major advancement in overcoming this problem.

Channeling acid is one type of gelled acid. Composed of hydrochloric acid and chemical additive agents, channeling acid does not restrict its action merely to the face of the well bore. Instead, long, narrow channels as large as ⅛ to ¼-in. in diameter are formed that extend a considerable distance into the formation.

Since the gelled acid is quite viscous when pumped into the well, it is restricted from entering the smaller pores in the formation. Consequently, it follows the larger permeable paths. As this acid reacts with the walls of these passageways, a film is formed, preventing further reaction. Additional acid, injected into the formation must penetrate deeper before it can react. Thus, the permeable pores in the rock are lengthened rather than broadened. The acid remains viscous only until it spends.

Once the initial extended channels have been formed, a second stage of conventional hydrochloric acid is forced into the formation. This acid penetrates the newly formed channels, stripping the residual film from the pore walls and enlarging the channel diameters.

Channeling acid is particularly effective for re-acidization. During re-stimulation operations using conventional acid, from 1½ to 2 times the volume of acid originally used is generally required. Since as much as 10,000 gal of conventional acid has been used on wells during completion, extremely large gallonages may be required for retreatment. In contrast, wells have been re-treated with channeling acid requiring as little as 16 per cent additional acid volume, compared to the 50 to 100 per cent additional volume normally required using conventional acid. The reduced amount of acid required for a successful re-stimulation treatment often results in reduced treating cost.

Combination Acid-Frac

A more recent development has been the combination of acidizing and fracturing in a single treatment. This

has been accomplished by the use of a gelled acid to carry the graded sand which is injected into the formation. The carrying fluid consists of kerosine, hydrochloric acid and a special emulsifying agent. Since the gelled acid does not spend rapidly, it penetrates to greater distances from the well bore. Sand acts to scour and prop open flow channels through which oil is produced. Such a treatment is especially beneficial to low permeability formations with highly fractured sections.

The second problem of avoiding loss of permeability caused by silicate swelling in acidizing deep lime wells has been especially difficult. Insoluble silicates in various limestone formations, such as the clay minerals, montmorillonite, beidellite, kaolin, and illite, tend to absorb liquid during acidizing and swell. Silicate particles which have been dislodged into flow channels may swell to 10 times their original size. Their blocking action can offset the benefits of the acidizing treatment or may even result in a lower production rate than before the treatment.

Silicate Swelling

The extent of swelling of silicate particles varies with the pH of the acid. As the acid spends and the pH approaches 2 to 3, the clay silicate reaches minimum size. As the acid spends further, the volume of silicates will again increase, as illustrated in Fig. 1. (The clay mineral used in this test consisted of 50 per cent illite, 20 per cent amorphous silicate and 30 per cent feldspar-quartz.)

Recently an additive to hydrochloric acid has been developed to limit the swelling of these clays by preventing the acid from spending beyond a pH of 3. As a result, when the acidizing reaction stops, the silicate particles are in a condition of minimum swelling, facilitating their removal from the well with the spent acid. This prevents the permeability of the formation from being blocked, so that there is no restriction to the subsequent production of oil. (Fig. 2).

Fig. 3 shows the range over which silicate control acid will minimize the size of the clay minerals occurring in various formations. Table 1 shows the quantity of insolubles released per 1000 gal 15 per cent hydrochloric acid in different formations in the East Texas area.

TABLE 1. Amount of insolubles released by 1000 gal 15 per cent acid.

Formation	Pool	Solubility of formation	Insolubles (in lb)
Upper Pettit Lime	Carthage	89%	228
Upper Rodessa	Red Springs	79%	490
Lower Rodessa	Red Springs	48%	1995
Lower Rodessa	Prairie Lake	91%	182
Jeter Lime	Sligo	39%	2880
Bacon Lime	Pickton	81%	432

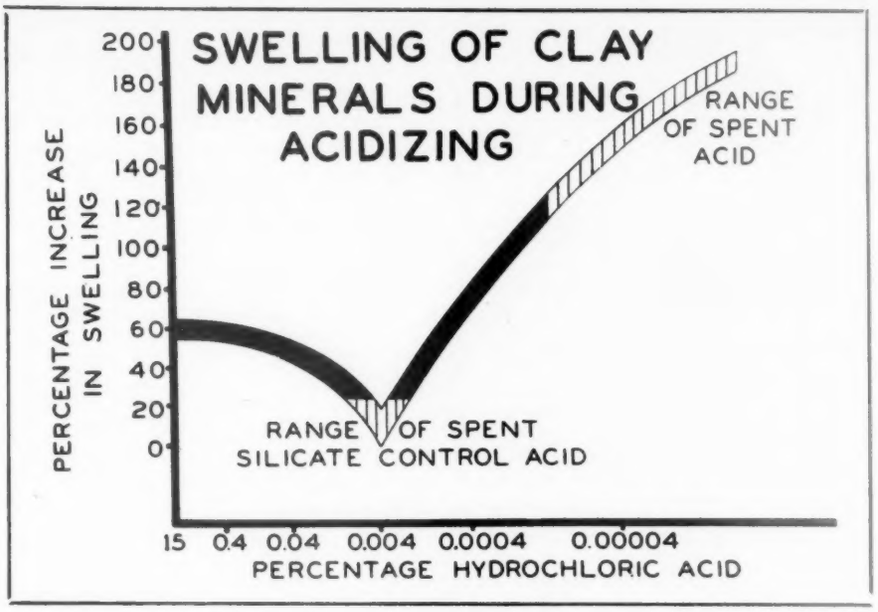


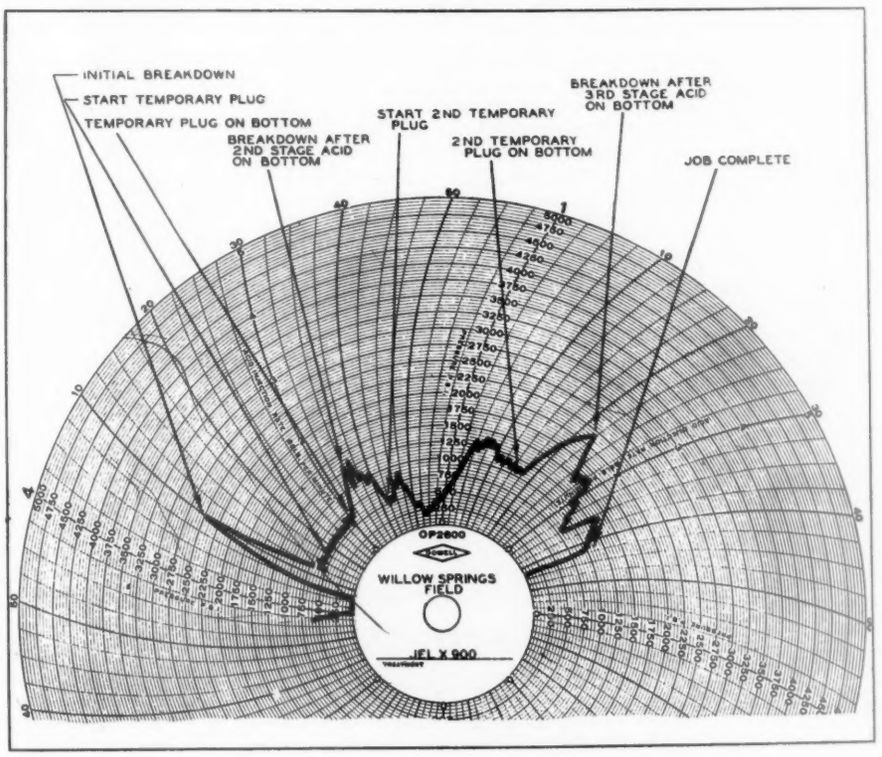
FIG. 3. Swelling of clay minerals during acidizing is graphically depicted. Curve shows the range over which silicate control acid will minimize the size of clay minerals occurring in various formations.

Temporary Plugging Agents

A third problem has been that of extending the benefits of acidizing over a greater vertical section of the pay. One answer has been the use of temporary plugging agents. A large number of permeability profile surveys of wells, before and after acidizing, indicated that in the majority of the treatments most of the acid was benefitting a limited section of the pay, usually between ½ and 3 ft. By the use of temporary plugging agents, these benefits have been extended over a greater formation interval.

During an acidizing treatment, the acid tends to follow the path of least resistance. As a result, most of it enters the more permeable sections of the pay zone. The temporary plug tends to block these more permeable sections, so that additional acid can be forced

FIG. 4. Typical recorded pressure chart of an acidizing job in East Texas where a temporary plugging agent was used.


INITIAL BREAKDOWN
START TEMPORARY PLUG
TEMPORARY PLUG ON BOTTOM
BREAKDOWN AFTER 2ND STAGE ACID ON BOTTOM
START 2ND TEMPORARY PLUG
2ND TEMPORARY PLUG ON BOTTOM
BREAKDOWN AFTER 3RD STAGE ACID ON BOTTOM
JOB COMPLETE
WILLOW SPRINGS FIELD
JEL X 900

The Author

Paul S. Clinkenbeard is district sales manager Shreveport, Louisiana, for Dowell, Inc., a position he has held since June, 1954. He received his BS degree in mechanical engineering from Oklahoma A&M College in 1949 and joined Dowell after graduation as a junior service engineer at Kilgore, Texas. Subsequently, he was promoted to service engineer and in January, 1951 was transferred to Bossier City, Louisiana. In September of that year he was made district engineer at Shreveport. Clinkenbeard was promoted to his present position in June, 1954.

into new sections of the pay. The temporary plug consists of a gelled liquid medium in which graded solids are suspended. During use, the solid particles bridge and filter out, forming an impermeable plug. This allows a pressure differential to be built up across the entire pay section until sufficient pressure is exerted to break down a new section. Batches of temporary plugging materials are alternated with acid in order to acidize additional sections. A more complete drainage pattern is created in this manner because a more complete acidization of the formation has been effected.

A good temporary plugging agent should meet certain requirements. It must be able to withstand the high bottom-hole temperatures encountered in deep wells in the East Texas area. The solids must be physically capable of withstanding high differential pressures. Control of the breakdown time of the gel is desirable. Fig. 4 illustrates the pressure build-ups encountered on a typical treatment using a temporary plugging agent.

TABLE 2. Use of temporary plugging agents in Willow Springs field, Gregg County, Texas.

Well	Quanity of acid per stage	Quantity of temp. plug per stage	Open flow potential on completion
A	2000 gal 2000 gal 4000 gal	9 bbls 12 bbls	130,000 MCF
B	2500 gal 2000 gal 2000 gal 2000 gal	14 bbls 12 bbls 10 bbls	170,000 MCF
C	2000 gal 2000 gal 4000 gal	9 bbls 12 bbls	107,000 MCF
D	750 gal mud acid and 2000 gal 2000 gal 2500 gal	12 bbls 24 bbls	135,000 MCF
E	2500 gal 2000 gal 2000 gal 2000 gal	14 bbls 12 bbls 10 bbls	280,000 MCF
F	5000 gal 2000 gal	11 bbls	290,000 MCF
G	5000 gal	None	60,000 MCF
H	5000 gal 4000 gal 1000 gal	None	4,700 MCF
I	1000 gal 5000 gal	None	4,600 MCF
J	5000 gal	None	7,000 MCF
K	None	None	2,950 MCF
L	None	None	12,000 MCF

Wells Treated

The largest number of treatments of this type in a particular field has been in the Willow Springs field, Gregg County, Texas. One or more temporary plugs have been used in 22 of the last 35 wells treated. It has been found that temporary plugs were more effective when used on wells having relatively thin pay sections. Table 2 gives the results of completing a number of gas wells in the Williow Springs field. Comparison of the final production figures shows clearly the increased benefits that were derived from the use of the temporary plugging agent.

The advances in acid treating have been numerous during the last few years. Those described are but some of the many new techniques and chemical additives used extensively in the East Texas area for acidizing deep limestone wells. These new services are increasing the ultimate recovery from available oil and gas reserves, and continuing research will undoubtedly result in even greater recovery in the future. * * *

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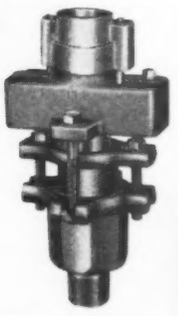

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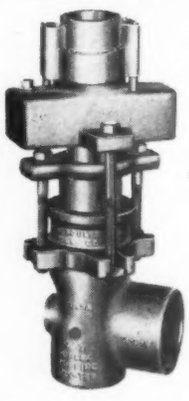

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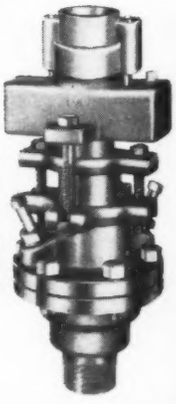

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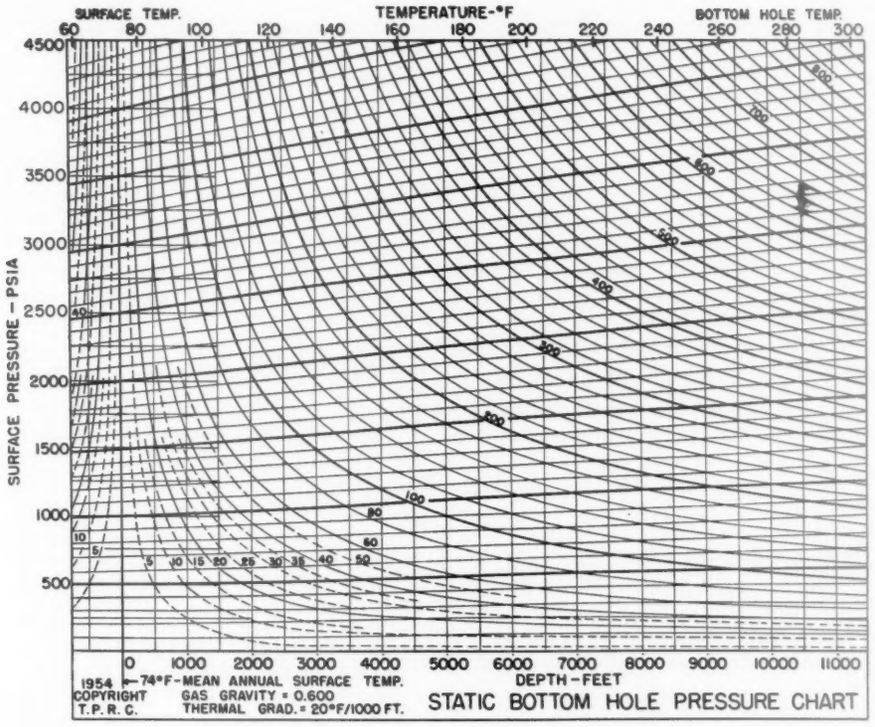

FIG. 1. Typical static bottom-hole pressure chart to determine accurately and quickly static bottom-hole pressures when surface pressures are known.

HOW TO DETERMINE

Static Bottom-Hole Pressure From Surface Measurements

Paul B. Crawford
Assistant Director, Texas Petroleum Research Committee

R. I. Bradford
Creole Petroleum Corporation

A. C. England
Ohio Oil Company

Henry Ince
Magnolia Petroleum Company

PRECISE bottom-hole pressures are necessary for calculating open-flow and deliverability of natural gas wells. The open-flow is required by state agencies for proration, and the deliverability is essential to all pipe line, reserve, market, and production computations in the gas industry.

Several hundred static pressure tests of gas wells are made per week in Texas alone in order to determine the bottom-hole pressure. A bottom-hole pressure instrument is used in only a small percentage of these tests. Presently, an accepted accurate method for determining bottom-hole pressures of deep wells is by direct measurement with a bottom-hole instrument. Such a test cannot be made on the ordinary dually completed well producing through the annulus. Frequency of this type completion has increased the desirability of being able to estimate accurately the bottom-hole pressure from surface pressure measurements. Continued drilling and production of gas from deep wells also has served to emphasize the need for bottom-hole pressure correlations that will yield precise, accurate results.

Recently the Railroad Commission of Texas authorized the use of a series of charts for estimating the static bottom-hole pressures of dry gas wells from surface measurements. The purpose of this work is to describe the procedure used in constructing the charts and demonstrate the precision and speed in using the charts.

Basis for Charts

Shut-in, bottom-hole pressures of dry gas wells may be precisely calculated provided the required data are known with sufficient accuracy. Normally, the time required to make a precise calculation is so great that as a result the procedure seldom is used except for infrequent comparative purposes. Rzasa and Katz have presented charts for estimating bottom-hole pressures using an average temperature and a trial and error procedure.[1] Poettmann presented tables and graphs to be used in estimating flowing or static bottom-hole pressures using an average temperature.[4]

Equation 1 may be used for estimating the bottom-hole pressure if the required data are available.

$$P_2 - P_1 = c \int_{h}^{h_2} \varrho dh \quad . \quad . \quad (1)$$

Where:
h = well depth
P = pressure
ϱ = gas density at depth h, a function of the compressibility, molecular weight, temperature, and pressure
c = conversion factor for units employed

Equation (1) was used to develop a series of thirteen charts, of which Fig. 1 is typical. A series of charts was developed to permit estimation of bottom-hole pressures for gas gravities ranging up to 1.1 gravity, well depths to 10,000 ft, thermal gradients up to 25F/1000 ft, and surface temperatures in excess of 60F. In developing the charts, it was assumed that:

a. The thermal gradient was constant from the surface to the bottom of the hole.

b. The gas density for gravities of 0.6, 0.7, 0.8, 0.9, and 1.0 (basis:air = 1.0) was properly described by its psuedo-properties originally presented graphically by Katz and later tabulated by others. The tabular functions listed in reference (3) were utilized in making the calculations. For gases of 1.1 gravity, densities reported by reference (2) were used.

c. Critical properties of the gas were those tabulated in reference (3).

d. The molecular weight of the gas was constant from the surface to the bottom of the hole.

To initiate calculations, a surface temperature of 74 F was used since this value has been found to apply to certain areas of the Southwest.[3] The charts were constructed, however, to be used in any area where the surface temperature is greater than 60 F. Equation (1) was integrated at 250-ft depth increments down to a well depth of 6000 ft. At this depth the integration interval was increased to 500 ft, and the integration continued to a depth of approximately 11,000 ft. Various surface pressures were assumed from near 200 to 4500 psia. Above psi the assumed surface pressures were all multiples of 500 psi. A similar procedure was used in starting at 74 F and integrating to obtain results for cooler surface temperatures.

Chart Description

Fig. 1 (a typical chart) shows the static pressure traverse for a well having a gas of 0.6 gravity (air = 1) and a thermal gradient of 20 F/1000 ft. The lower abscissa shows the well depth in feet. The upper abscissa shows the temperature at the corresponding well depth. The ordinate shows the pressure in psi. The slightly inclined lines show the pressure traverse such as might be recorded in lowering a bottom-hole instrument into a gas well. The approximately hyperbolic curves show the difference in pressure between the pressures at the indicated well depth and the surface pressure. The bottom-hole pressure is equal to the surface pressure plus the pressure shown on the substantially hyperbolic lines.

Applicability of the charts will depend on the degree to which the assumptions describe the actual well conditions. The psuedo-compressibility correlations have been indicated to be accurate to within two per cent in some instances. If such is the case, then the pressure difference shown on the substantially hyperbolic lines may be accurate to within two per cent. If a surface pressure of 3000 psi were found by a dead-weight gage and a pressure difference of 400 psi ± 2 per cent were indicated by the chart, then a bottom-hole pressure of 3400 ±8 psi would be expected. The variation of ±8 psi is approximately 0.25 per cent of the bottom-hole pressure, which may be as precise as some bottom-hole instruments. The actual chart precision will depend on the relative values of the pressure difference to the total pressure.

The series of charts has been compared with observed results for well depths down to 10,000 ft. In all but a few instances, the chart was within a few pounds (generally about 5 to 6 psi) of the supposedly precise bottom-hole pressure. If surface pressure, subsurface temperature, and gas compressibility data are known accurately, it may be possible to calculate a bottom-hole pressure to a precise value. Caution always should be exercised when applying generalized charts to specific reservoirs to ascertain that the specific reservoirs and gas properties conform reasonably well with the assumptions.

Specific Reservoirs

In addition to using the charts as general charts, it is suggested that specific charts be prepared for certain leases or areas of gas reservoirs. By using the chart series for interpolation, a single chart for a specific lease may be calculated, plotted, and inked in about two days time. Considerable computation and measuring time may be saved during its use throughout its applicable life of the reservoir, after which a second chart should be prepared and used. Properties of gas produced from some areas of gas reservoirs change only slightly or not at all during a year, and a single chart may be applicable for a considerable length of time.

Applications

A few examples are presented to illustrate the application of Fig. 1 for estimating the static bottom-hole pressures of dry gas wells:

A. Direct Reading

The chart may be read directly to estimate the bottom-hole pressure for certain cases.

Given:
Surface Temperature = 74 F.
Tubing or Casing Raw Gas Gravity = 0.6
Thermal Gradient = 20 F/1000 ft
Well Depth = 8258 ft
Surface Pressure = 1783 psi

Solution:

a. To compute the bottom-hole pressure, first spot the well-head conditions on Fig. 1. By comparing the upper and lower abscissas, it will be noted that a zero well depth corresponds to a 74 F surface temperature. Use the ordinate (Y-axis) to find the surface pressure of 1783 psi. The light, exactly horizontal lines (abscissa) are surface pressure lines and are shown at 1500, 1750, 2000 psi, and so on. This point of intersection (temperature and pressure) gives the well head conditions. It is shown by an "X" on the graph.

b. At the well depth of 8258 ft, proceed vertically upward to the intersection of the "path line." The "path line" is a line starting at the well head condition and drawn parallel to the slightly inclined lines. This intersection is shown by an "X."

c. Read the value of the hyperbolic curve. It is 345 psi. This is the weight of the gas column.

d. The bottom-hole pressure is equal to the surface pressure plus the weight of the gas column.
BHP = 1783 + 345 = 2128 psi.

B. Surface Temperature Exceeds 74 F.

1. Direct Reading:

If the surface temperature differs from 74 F, the upper left-hand portion of the chart should be used as follows:

Given:
Surface Temperature = 93 F
Gas Gravity = 0.60
Thermal Gradient = 20 F/1000 ft
Surface Pressure = 2415 psi
Well Depth = 6238 ft

Solution:

a. Use the temperature scale at the top of the chart to find the surface temperature of 93 F. Proceed vertically downward to the intersection of the surface pressure of 2415 psi. This point is shown by a dot. Read the value of the hyperbolic curve as 63 psi. Using the "X" axis, note that a surface temperature of 93 F corresponds to an equivalent increment in well depth of 1000 ft.

b. At the equivalent well depth of 7238 ft (6238 ft actual depth plus 1000 ft equivalent increment) proceed vertically upward to the intersection of the path line. This point of intersection is shown by a dot. Read the hyperbolic curve as 410 psi.

c. The weight of the gas column is equal to 410—63 = 347 psi
BHP = 2415 + 347 = 2762 psi

The chart series is designed to permit calculations for gas gravities ranging from 0.6 to 1.10 and thermal gradients from about 5 to 25 F/1000 ft.

Acknowledgment

The authors wish to thank Dr. George H. Fancher, director, for encouragement of the work. C. W. Binckley, J. A. Hall, J. G. Jewell, Dr. D. L. Katz, Ralph J. Schilthuis, and R. V. Smith have made valuable suggestions. Appreciation is expressed to the research committee for permission to publish the results.

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1. Rzasa, M. J., and Katz, D. L., "Calculation of Static Pressure Gradients in Gas Wells," Trans. AIME 160, 349 (1944-45).
2. Standing, M. B., and Katz, D. L., "Density of Natural Gas," Trans. AIME 146, 140 (1942).
3. *Back Pressure Tests for Natural Gas Wells*, Railroad Commission, Austin, Texas.
4. Poettmann, Fred H., "The Calculation of Pressure Drop in the Flow of Natural Gas Through Pipe," Trans. AIME 192, 317 (1951).

A set of 13 charts covering a range of gas gravities and thermal gradients is available from the Texas Petroleum Research Committee, A and M College, College Station, Texas, which should enable the user to calculate over 90 per cent of the volume of static bottom-hole pressures with greater reliability, accuracy, and economy than heretofore. The optional use of these charts has been authorized in Texas by the Railroad Commission in accordance with the procedure outlined in Form GWT-4.

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Underground Gas Storage

in the Appalachian Area

Frank A. Boyd†

THE storage of natural gas consists of placing gas in a closed container during periods of low demands on the pipe line system and of removing this gas during periods of high or peak demands.

In the distribution of gas to ultimate consumers, small containers, located near individual market areas, are most desirable. Large volume containers, at practically any location, are of importance to the entire transmission system.

Various types of containers, such as steel tanks, sections of pipe, and underground "sand" reservoirs may be used for this purpose.

This paper will be limited to the storage of natural gas in underground "sand" reservoirs and further limited in that the data and procedure used will apply primarily to the Appalachian Area.

Reasons for Storage

A great deal has been written on the various reasons for the storage of gas. There is actually only one reason for such storage and that is economics. By the utilization of suitable storage areas the overall cost per MCF of gas delivered is less than if such storage were not used. There are many ways in which storage does reduce costs to the ultimate consumer. To specifically mention a few, storage:

(1) Provides additional capacity for winter heating loads.

(2) Provides a company the means to more efficiently utilize its pipe line system.

(3) Permits a company to produce its full share of reserves in a competitive field.

(4) Permits the ultimate utilization of small stripper wells.

(5) Permits efficient utilization of total gas reserves.

(6) Permits companies to purchase gas at a high load factor.

A clarification of the above points as to how they apply in the Appalachian Area requires a brief history of the gas business in that area.

The operating companies initially had sufficient deliverability in their wells to permit a large number of them to be shut in during the summer; and as the demands increased due to colder weather, they were able to meet this demand by merely turning additional wells into line. Due to the convenience of gas as a heating fuel, and to the fact of the sky-rocketing price of coal and fuel oil, more and more people clamored for gas for heating purposes. Also, many large industries, even though they used a lower grade coal, felt justified in switching to gas for many basic and finishing processes. Although, on a yearly basis, there was sufficient gas to meet this demand, storage became necessary to serve as a balance in meeting the higher winter requirements.

Initially, consuming areas were supplied by gas pools located within a short distance of markets. As these fields were depleted, however, it became necessary to utilize fields farther from consuming areas. This in turn necessitated the laying of additional transmission facilities. Over a period of time, the fields became farther and farther from the large consuming areas so that by the middle 1930's, most of gas being used in the Pittsburgh area was being transported from West Virginia.

It was these old fields, located near consuming areas, that were first activated for storage, thus enabling fairly constant load factors on transmission lines from the Appalachian producing areas. This saved considerable capital outlay on the part of the distributing companies by permitting the utilization of their present lines rather than laying new large diameter lines.

Although conservation is not regulated, it is practiced rigidly by the individual companies in the area, as you might well realize when the average production per well is 10,000 cu ft and several thousand wells are being produced whose production is less than 5000 cu ft per day. Undoubtedly, a large percentage of these wells are not economical to operate, but a far larger percentage can be operated profitably if they are permitted to produce at their full capacity every day in the year. Underground storage permits this year round production.

Many fields in this area, although containing fairly large total reserves, have a low permeability. By the utilization of storage, these fields can constantly be produced and the gas placed in a reservoir of higher permeability, thus making reserves more readily available during periods of high demand.

When the Appalachian area was no longer able to meet all demands of its customers and to assure a guaranteed supply to potential customers, it was necessary to import gas from the Southwest; the first long distance transmission line began service in 1944. Because of fixed charges, the cost per MCF of gas purchased from a pipe line company increases as the load factor decreases. It is, therefore, essential that a high load factor be maintained in order to obtain this gas at the lowest possible cost.

†Texas Eastern Transmission Corporation.
Condensation of paper presented before the Tenth Annual Short Course in Gas Technology; Texas College of Arts and Industries, June 2, 1955.

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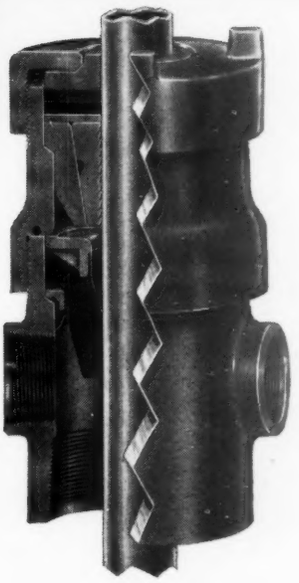

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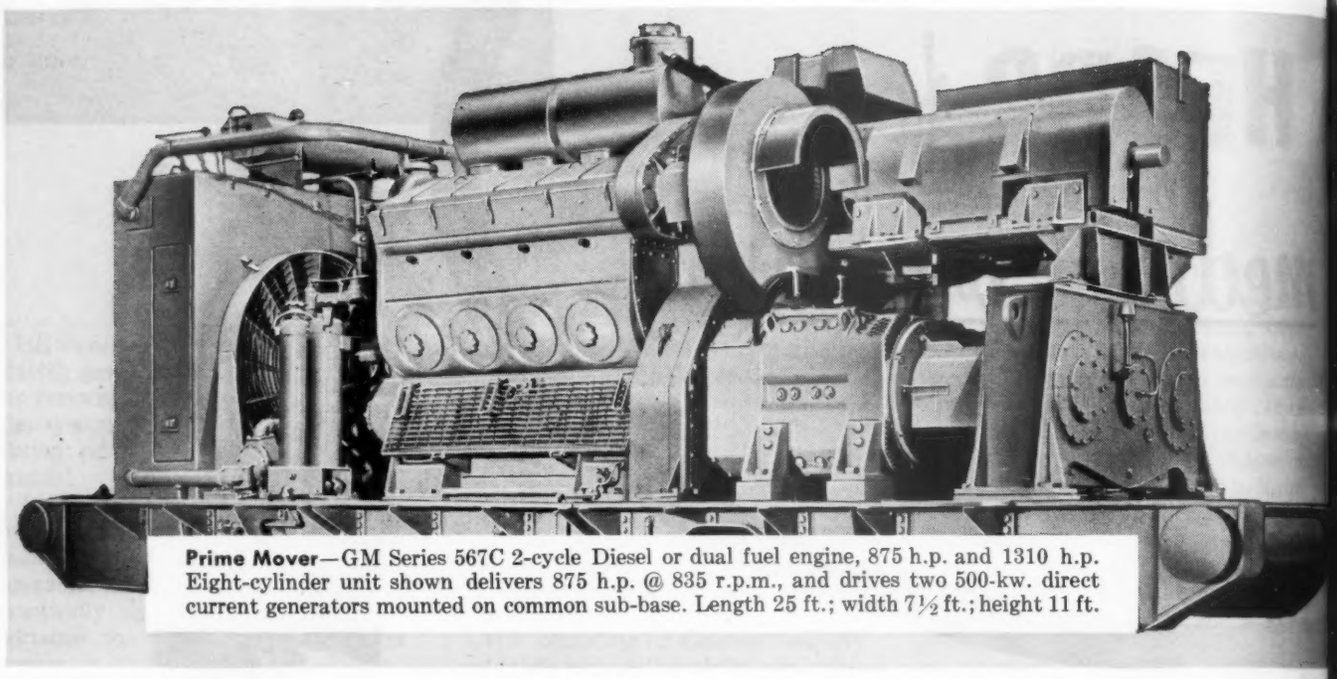

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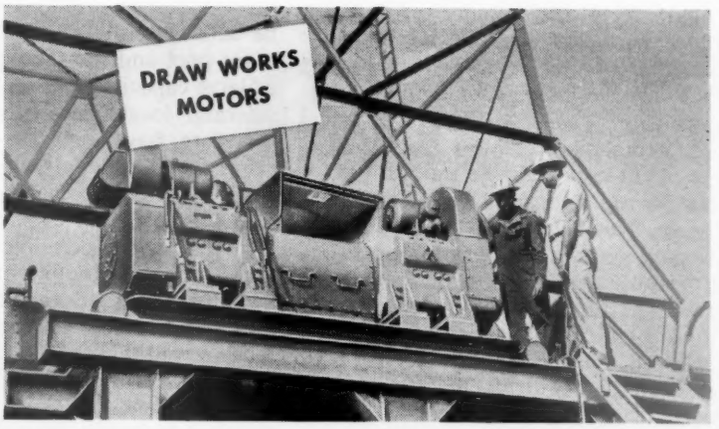

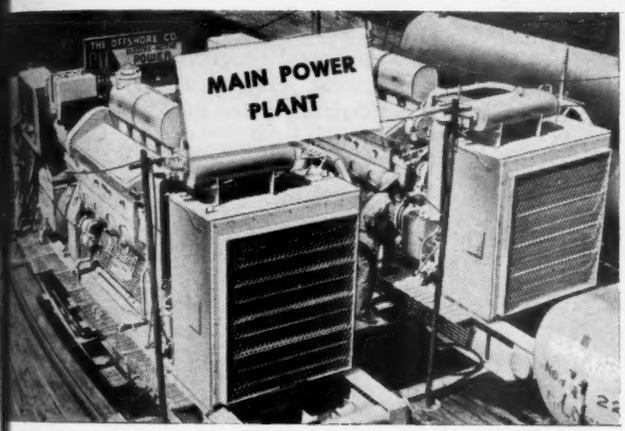

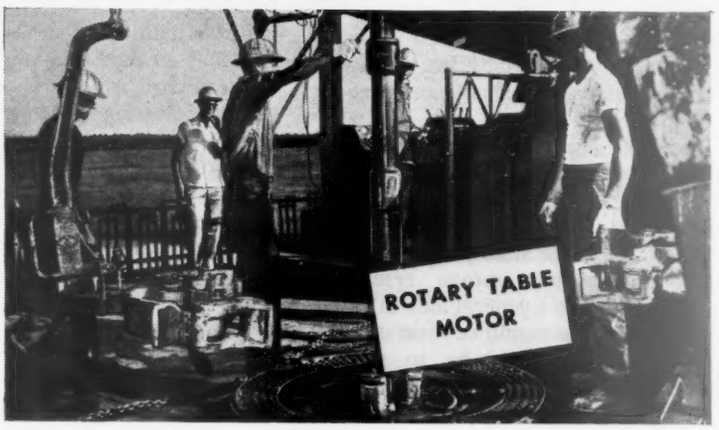

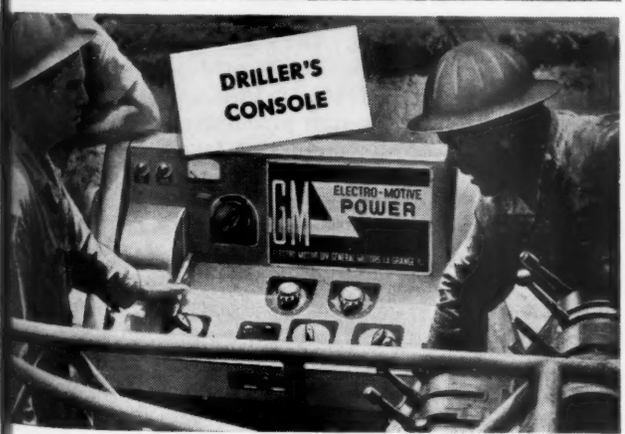

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Type of Storage

Classified as to use, there are three basic types of underground storage reservoirs:

(1) A relatively large field to supply deliverability over a long period of time, even to the extent of being turned on at the beginning of the heating season and kept on line the entire winter. This type of field would have a small decrease in deliverability with a proportionate drop of total gas in place.

(2) A second type of field is one that would supply deliverability for an extended period of possibly one to two weeks.

(3) The third type of field is one which is relatively small in size, but with a high deliverability, something that might approach the rate of 100,000,000 cu ft for each 1 billion cu ft in storage. This field would be used only for very short periods of time, one, two or possibly three hours at the most, when the furnaces come on in the morning and people start to prepare breakfast. Later in the day, gas can be taken from either of the first two mentioned fields, and placed in this peak load field.

Now that we have covered the reasons for storage, a brief history of storage, and the basic types of pools, let us assume we are an operating company within the Appalachian Area, and specifically within Pennsylvania, and find that our company needs a storage field. Just what would be involved?

The first step in attempting to locate our underground storage reservoir would be to have a general idea in what area such a field would be most useful. The next step would be to secure property maps of a considerably larger area and begin to locate all of the wells on this map. Before going further, I would not wish to imply that the location of every pool might be this difficult. Pennsylvania has many fields that are well defined and complete records would not be difficult to obtain. However, this will be one of those difficult situations in order to bring out just how much work and time might be involved.

A visit to each of the oil and gas companies would be necessary to examine their maps to obtain the location of all wells known to them. Old Geological Survey books and topographic maps would also be utilized in obtaining well locations.

From these preliminary data a sand map of the area would be drawn to determine whether a closed reservoir exists. Upon completion of our preliminary sand map, we might have indicated several different horizons which appear to be "closed." Most of the pools in the Appalachian Area are not dependent on structure, but are lenses accused by permeability "pinch-outs."

Of the pools indicated, one appears to offer good storage possibilities. The open flow of the wells are noted from some of the records that seem to be reasonably correct, and assuming a porosity and knowing the sand thickness and thickness of the pay zone from some of the better well records available, we decide to explore further the possibilities of this one pool.

Assuming that this particular pool was discovered, drilled, and depleted prior to 1900, additional records will be difficult to obtain. The discovery of a gas pool and the subsequent drilling of large capacity wells does create considerable local interest, however. We, therefore, have someone begin examining the files of all old newspapers published in the general vicinity and also start upon an examination of all available records pertaining to property and leases in the county recorder's office. Another good source of information would be elder residents who might recall a well that they had seen or that had been mentioned to them by one of their friends as being in a certain location. When we have obtained all possible data concerning the wells and can find no particular disadvantage to this reservoir as a storage area, an intensified leasing program is then in order.

Being an operating company in this area, we will already have some wells and leases within the pool limits. Being old leases, however, they will not be applicable for storage operations. It will be necessary to contact both the owners of the oil and gas and the surface owners, if different, of each of these properties to obtain a modification or a supplement to the original lease, to obtain the right to inject, store, and remove natural gas under that particular property.

There has been very little sale of royalty interests in this section of the country, but still it is sometimes quite difficult to run down all of the interests.

The storage lease form most commonly used in this area provides that the lessor shall receive an annual payment for each well on his property. If there are no wells, the annual payment is based upon the number of acres covered by the lease. The leases are for a term of "ten years and as long thereafter as storage operations are being conducted." The company is the judge as to whether or not the particular tract involved is actually being used for storage.

As there might possibly be future construction on some of the properties, or maybe due to extremely good farm land, the owners might want assurance that there would be no wells drilled on their property. In cases of this kind, it is so stipulated in the lease that through those wells on other propetries, gas may be injected under, stored in, or removed from formations under the property, but that no drilling operations will be conducted. It might be necessary to purchase some properties "in fee."

Even with these three alternatives—a general storage lease with the right to drill, a storage lease with no drilling permitted, or the outright purchase of a property—it is, in a large number of cases, virtually impossible to control completely all access to the formation within the proposed storage area. Generally, this is not too serious because the operating companies, realizing that without condemnation, complete control cannot be acquired, have respected other companies' storage areas.

Before actual construction begins, we need to know, within reasonable limits, the capacity of the pool, its potential deliverability, and pressures that will be encountered in operations.

As the pool in which we are interested is old, total production data are probably non-existent. There might be some records available for certain individual wells regarding their deliverability and total production and these records must serve as a guide in an overall estimation for the field.

Installing Facilities

By using known data as to individual well deliverabilities and production, together with logical assumptions and estimates, we can arrive at figures that are within allowable limits of accuracy for the design of the compressor station and pipe line system.

It has frequently been decided, after a storage pool has been in operation for a few years and its results proved satisfactory, to raise the pressure above that for which the field was originally designed. This, in turn, may necessitate laying heavier pipe lines, installing additional compressor facilities, and in some instances, even re-working formerly abandoned wells that had been plugged to withstand only the lower pressures. To prevent this, be generous. Design for the ultimate, even though it may not seem necessary now. Actual installation of facilities may be taken in steps. In most instances, for a field having a turnover of 25 billion cu ft a year, no well line should be less than 6 in. in diameter and no main field line less than 20 in.

Dehydrators and scrubbers should be designed for at least one and one-half times the foreseeable peak day demands upon the field and at least two extra meter runs should be provided. In order to provide greater flexibility of operations, it is essential, in my opinion, that there be a gate on every

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well gathering line at the point where it enters the main line system. This permits conservation of manpower, as it is then unnecessary to shut in individual wells, but groups of wells may be closed off by means of only one gate. Main line gates should be installed in sufficient numbers so that no more than four well gathering lines would be connected between these main line gates. The main line gates readily permit entire portions of the field to be isolated.

We still have the problem of making sure within the limits of human ability that we have located all wells that were ever drilled within our area in order that they may be reconditioned or properly plugged. These wells must include not only those wells drilled to the sand in which we contemplate storing gas, but also all of those wells that have been drilled through this sand to deeper formations. It actually boils down to the fact that being an old field, every well must be gone into. We cannot be sure that some well that, according to available records, was supposed to be a shallow well, might not have been drilled to the storage formation or deeper.

Most of the wells within our area will be located either from our own company's maps, or from the maps of other companies. There might be some wells that will be located by information supplied by elderly residents of the area, or from local newspaper files and county court records.

In many cases of abandoned wells, where the pipe has been pulled, there will be no surface evidence whatever to indicate the location of the old hole, and it may be necessary to bulldoze a large area before discovering its location. There even may be instances where buildings or roads have been constructed over the old hole. Even in cases where the pipe has not been pulled, the site may now be entirely covered by several feet of dirt. It might not even be unusual to find a well covered with 8 or 10 ft of soil with its original closing in equipment still intact. Such a well would probably be located near a road, having been covered over in the process of grading.

In cases where it is indicated that a building has been constructed over the old well, it might be necessary to purchase and move or demolish the building before the search can begin. Specific problems in connection with the location of these "rumored wells" are too numerous to mention, but I believe you can readily understand the many difficult situations that can arise.

Within our theoretical gas storage pool, there are both active and abandoned wells. Some of these abandoned wells will have been plugged in accordance with usual procedures at the time they became non-productive. Such plugging might involve wooden plugs, cement, and gravel. In other instances, anything that was available, such as wrenches, bits, bailers, small size tubing, and anything else that was handy, might have been thrown into the old hole.

Problems of Cleaning Out

Many problems arise in connection with cleaning out some of these old holes due to the "junk" that was originally thrown in. In addition to the use of impression blocks to locate material, a fixed focus camera, which takes a 360-deg photograph in a 3-in. hole, has been designed and used successfully.

Most of the cleaning out work and reconditioning of wells is done with spudders and to a lesser extent by National Machines. The old hole must be completely cleaned out to bottom; old casing and tubing, if any, removed and replaced with pipe of a suitable size and strength to take care of maximum contemlated storage pressures. In the majority of cases, pipe, other than the producing string, should be cemented to the surface or filled with other nonporous material.

In so far as the well program is concerned, we must:

(Pat. Pend.)

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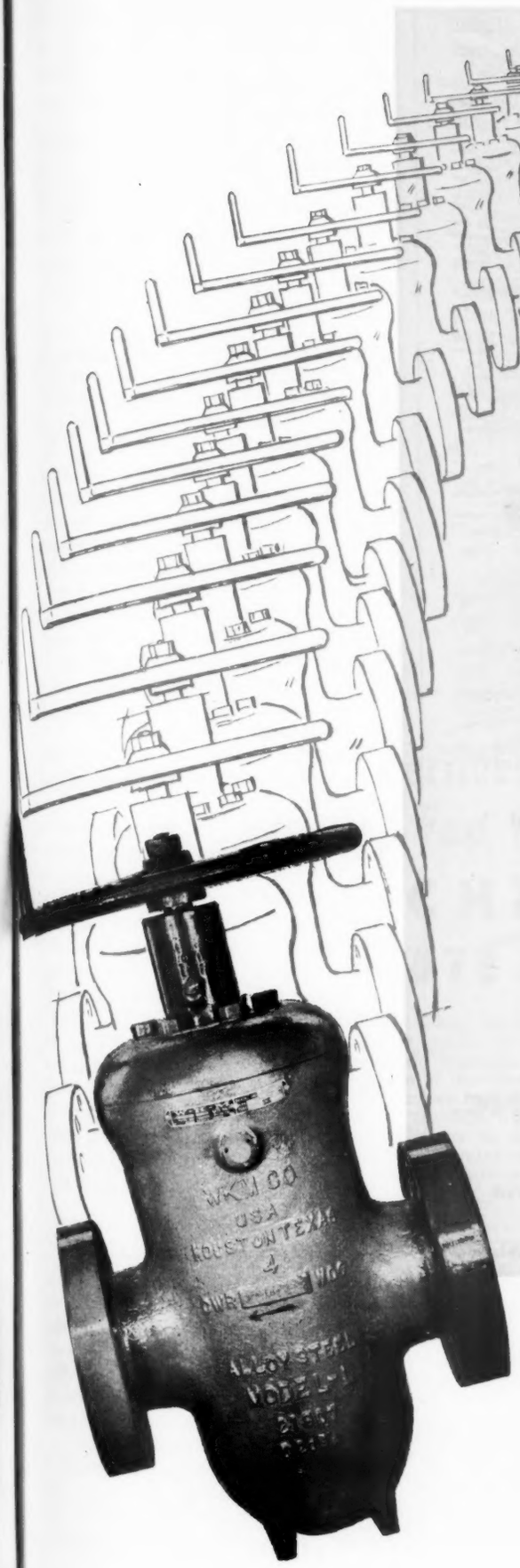

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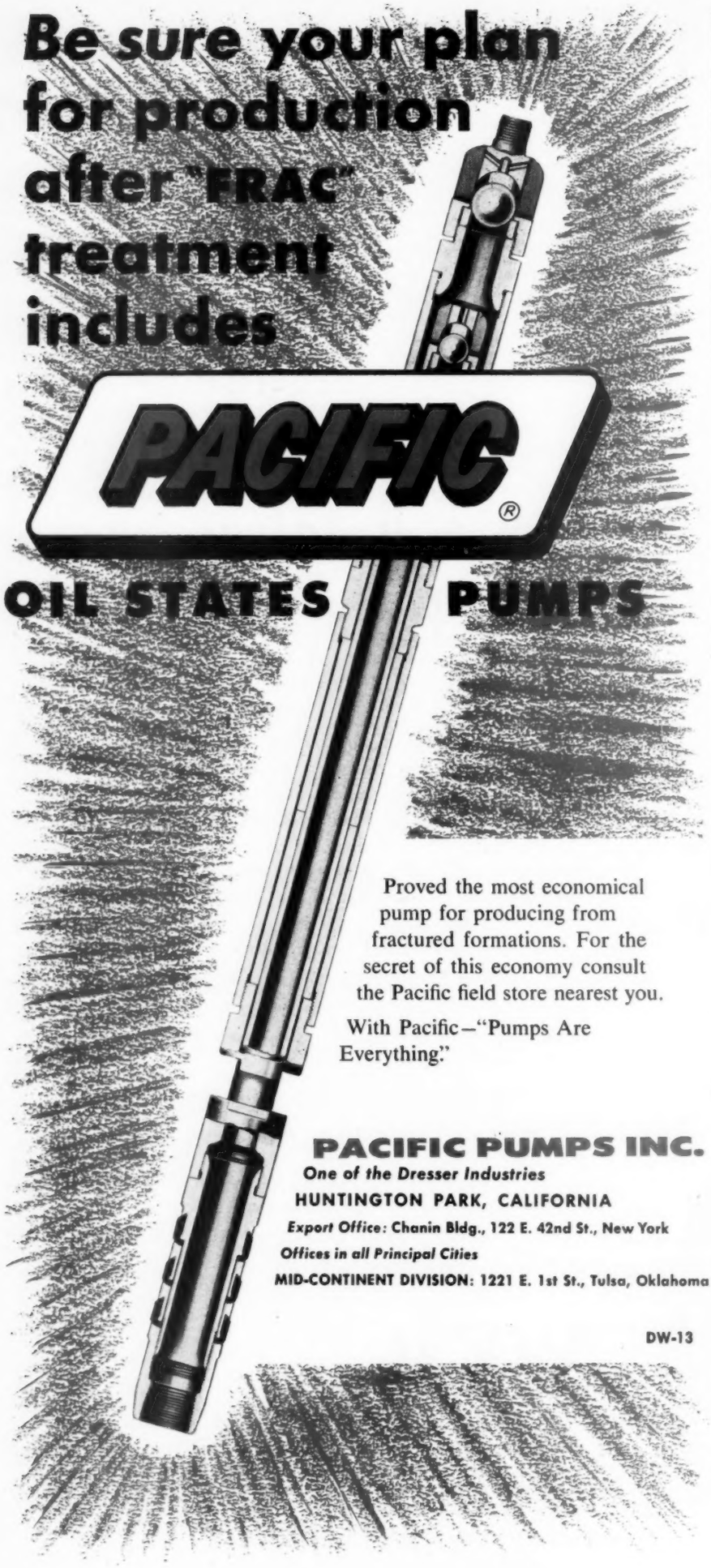
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(1) Reclaim and recondition abandoned wells.
(2) Replug abandoned wells.
(3) Recondition active wells.
(4) Plug active wells.
(5) Drill new wells.

Not all wells cleaned out will necessarily be used for the injection or removal of gas, but will, by installation of recording gages, serve admirably as observation wells.

After a well has been properly cleaned out and cased, it would be advisable, by means of a small portable compressor, to subject this well to various rates of flow in order to determine its productive characteristics and also to determine better the ultimate capacity of the pool.

It might at times be advisable to have orifice meters on the individual wells that are actively used for storage. Personally, I do not think that this is necessarily essential as the overall pool characteristics are what is desired. By the use of data gained from the initial testing, estimates of deliverability within reasonable limits can be obtained for the field and further refinement made in these estimates as the field is put into operation.

We now have all of our wells reconditioned, pipe lines laid, compressor station built, all necessary leases have been acquired and shops and warehouses constructed, and have injected our cushion or base gas.

What percentage of our total delivery might we expect to receive from storage?

In the course of a recent survey, it was revealed that approximately 26 per cent of the total gas delivered during a winter period came from storage. As storage primarily benefits the heating consumers, a further breakdown reveals that of total deliveries to heating consumers, 68 per cent was delivered from underground storage. On a peak day, deliveries from storage were 52 per cent of the total. Considering the high percentage of gas delivered from storage, it is understandable that it is now practically impossible for a company operating in the Appalachian Area to grow or even exist without this vital facility.

The Problem of Freeze-Ups

Of the many operating problems, one that has plagued most operators of high pressure gas storage pools during withdrawal periods has been "freeze-ups" in wells and field lines due to the formation of hydrates. Formations of hydrates in a well or line causes a constriction resulting in reduced flow.

"For many years, the so-called 'freezing' of natural gas pipe lines was assumed to be merely the result of the formation of water ice, and whenever

the temperature surrounding pipe lines was higher than the freezing point of water, it was assumed that freezing of the lines was due to the reduction of the temperature within the pipe to 32 F, or lower, by the expansion of the gas passing through some local constriction. Eventually, however, it became generally recognized that these freezes, many times, are caused by the formation of these hydrates, which are crystalline compounds formed by the chemical combination of natural gas and water and which form under pressure at temperatures above the freezing point of water."

All natural gas as it comes from the well contains some water and therefore under certain operating conditions, hydrates may form in the well connections or in the gathering lines ahead of the dehydration plant. Many manhours may be devoted, during withdrawal periods, to unfreezing wells and gathering lines.

There are at present several makes of dehydrators and separators available to place on wells or field gathering lines. In addition, there are units available for the injection of methanol into the gathering system to inhibit hydrate formation.

No one method seems to completely control the formation of hydrates at the well head during withdrawal periods. and for some reason, that is at least unknown to me, one field might respond favorably with the use of separators whereas another field would require dehydrators or alcohol injection.

The end result probably means trying all three standard procedures on certain selected wells and then using throughout the rest of the field the one found most desirable. In general, some type of individual wellhead dehydration is indispensable in a high pressure field.

In the annual injection and withdrawal of gas, problems always arise as to pressure limits of the field, particularly with respect of how low a pressure can be tolerated at the end of the withdrawal period, and how high a pressure we might have at the end of an injection period.

The lowest operating pressure is controlled by two main factors:

(1) The field pressure necessary to maintain a required deliverability at the end of the withdrawal season, and

(2) In the event of edge water, the pressure necessary to prevent encroachment.

On the other side of the scale, as to how high a pressure we might have, there are three limitations:

(1) Limitation in the amount of storage gas available.

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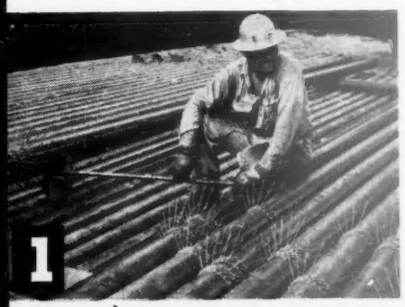

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(2) Limitation of the facilities and length of injection season to store available gas.
(3) Limitation in pressure due to the nature of the reservoir.

For most reservoirs, only a rough approximation can be made in estimating future deliverabilities for a period longer than the next eight or ten days. A field with a certain amount of gas in storage will have one deliverability today and two weeks from now might have an entirely different deliverability with the same amount of gas in storage. This change, of course, is the result of the manner in which the field is operated within that two-week period. If gas is stored during the first week and withdrawn the second week, we will have a much lower deliverability than if gas had been withdrawn the first week and stored during the second week.

Even with all of the data available, including rock pressures, back pressure flow tests, etc., we usually discount our answer by as much as 50 per cent to allow for coning in the field. Still, all of our tests and compilation of data are of importance, as every particle of factual knowledge obtained will be of benefit in the continued good operation of the field, and will provide material for more accurate estimations.

As storage continues to grow in this area, the acquisition of suitable fields becomes more difficult and the cost of development becomes higher. The best fields and the easiest fields have, to a large extent, already been activated. Land owners and independent operators are now demanding higher payments for their interests in potential storage fields.

If these costs of acquisition continue to rise, the gas industry in general, and those concerned with storage in particular, might be in the position of having to charge such a high price for their commodity that other fuels will tend to replace gas.

To the best of my knowledge, only the states of Illinois, Michigan, West Virginia, Kansas, Kentucky, and Oklahoma have passed legislation allowing condemnation for the underground storage of natural gas. There are several other states considering such legislation. Pennsylvania is one of them.

A bill has been introduced in the United States Senate that is intended to permit condemnation for underground storage purposes.

In conclusion, the underground storage of natural gas is necessary for the continued growth of the gas utility companies. The acquisition and development of suitable areas may, at times, be difficult. The problems encountered can be overcome if we fully utilize the technical and practical knowledge that is available within the industry. * *

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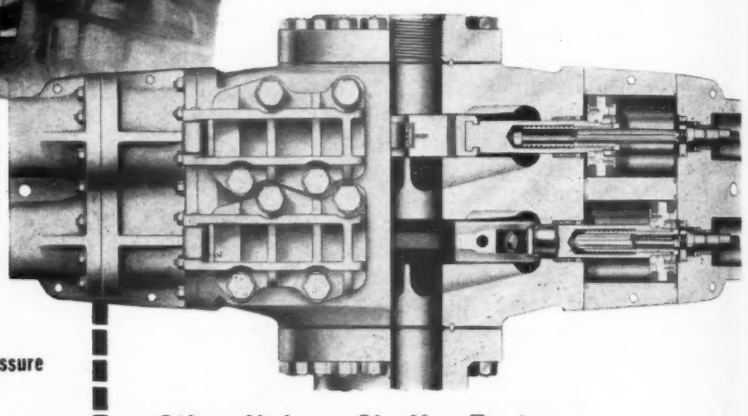
Cutaway view of Shaffer Hydraulic Double Cellar Control Gate showing clean, simple design.



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Flooding is in its infancy at KMA and experience shows that oil can be moved through the reservoir by water injection

Shell Oil Co. Preston "A" Project

This project is a pilot flood of the KMA Zone 1 reservoir on the D. R. Preston "A" lease, in the south half of sec. 20, H.&T.C. RR. Co. survey, block 7.

History Before Waterflooding

Drilling on the Preston "A" lease was begun in October, 1938, and completed in January, 1942. In early development of the lease, the wells were completed with 7-in. casing; later wells were completed using 5½-in. casing. The casing was set and cemented near the top of Zone I for most of the wells. All of the 16 wells drilled were shot with nitroglycerin at the time of completion. By December, 1946, pumping units had been installed on all producing wells. Well No. 13 was converted to a gas-injection well in June, 1941.

The initial gas injection into well No. 13 was approximately 120 Mcf per day at 980 psi input pressure. When the pilot flood was initiated in December, 1950, the gas injection was approximately 70 Mcf per day at 600 psi input pressure.

Structure maps contoured on the top of Zones I and II (Fig. 22 and 23) illustrates the respective subsurface configuration of the two zones. Fig. 24 is an isopachous map of Zone I and Zone II, showing the gross thickness of the two respective zones. The Preston "A" lease contains 237 productive acres, and the flood pattern within the lease contains 21 acres.

Zone I was the only section flooded, as Zone II is unproductive in the area. The gross Zone I reservoir volume for the lease is 12,321 acre-ft, with an average gross thickness of 52 ft. The gross Zone I reservoir volume for the flood pattern is 1135 acre-ft, with an average gross thickness of 54 ft.

The cumulative oil production for the lease to December, 1950, when flooding was begun, was 1,045,293 bbl or an average of 4411 bbl per acre. Cumulative oil production for the two wells affected by the pilot flood, well No. 12 and well No. 15, was 128,431 bbl before injection was begun. By December, 1950, daily output had declined to approximately 11 bbl of oil.

Development of Waterflood

A temporarily abandoned salt-water-disposal well, the D. R. Preston "A" No. E-18, which had produced from the Ellenburger limestone, was recompleted as an input well for injecting water into Zone I. In recompletion, the well was plugged back and jet-perforated through the casing opposite Zone I with four shots per foot for 42 ft.

Water injection was begun in December, 1950, and continued to December, 1951, when the project was abandoned. The initial injection rate into the well was approximately 290 bbl water per day and was later maintained at approximately 370 bbl per day until the project was discontinued. Water entered the wellhead under a vacuum for the entire duration of the project.

EXCLUSIVE

A total of 147,000 bbl of water was injected into Zone I through Well No. E-18 to December, 1951, a daily average of 9.7 bbl per foot of gross sand thickness. The average ratio of injected water to produced oil for the duration of the pilot flood was 3.6:1.

Well No. 12 and well No. 15 were the only two wells that showed an increase in oil production resulting from the water injection. In September, 1951, after 84,000 bbl of water had been injected, the daily oil production increased from 11 to 18 bbl for well No. 12 and from 11 to 20 bbl for well No. 15. Daily production continued to increase until well No. 12 was producing 20 bbl and well No. 15, 28 bbl, at which time the water-injection program was discontinued.

Source and Treatment of Injection Water

Injection water for the project was obtained from two "watered-out" Ellenburger wells. It was not treated, but a closed system was maintained. The injection water was pumped from the source wells to a tank having an oil seal on top of the water; from the tank, the water flowed by gravity into the input well. The sand-face pressure, as determined from the water level in the injection well, gradually increased during the injection period to about 120 to 130 psi, where it remained until the project was discontinued.

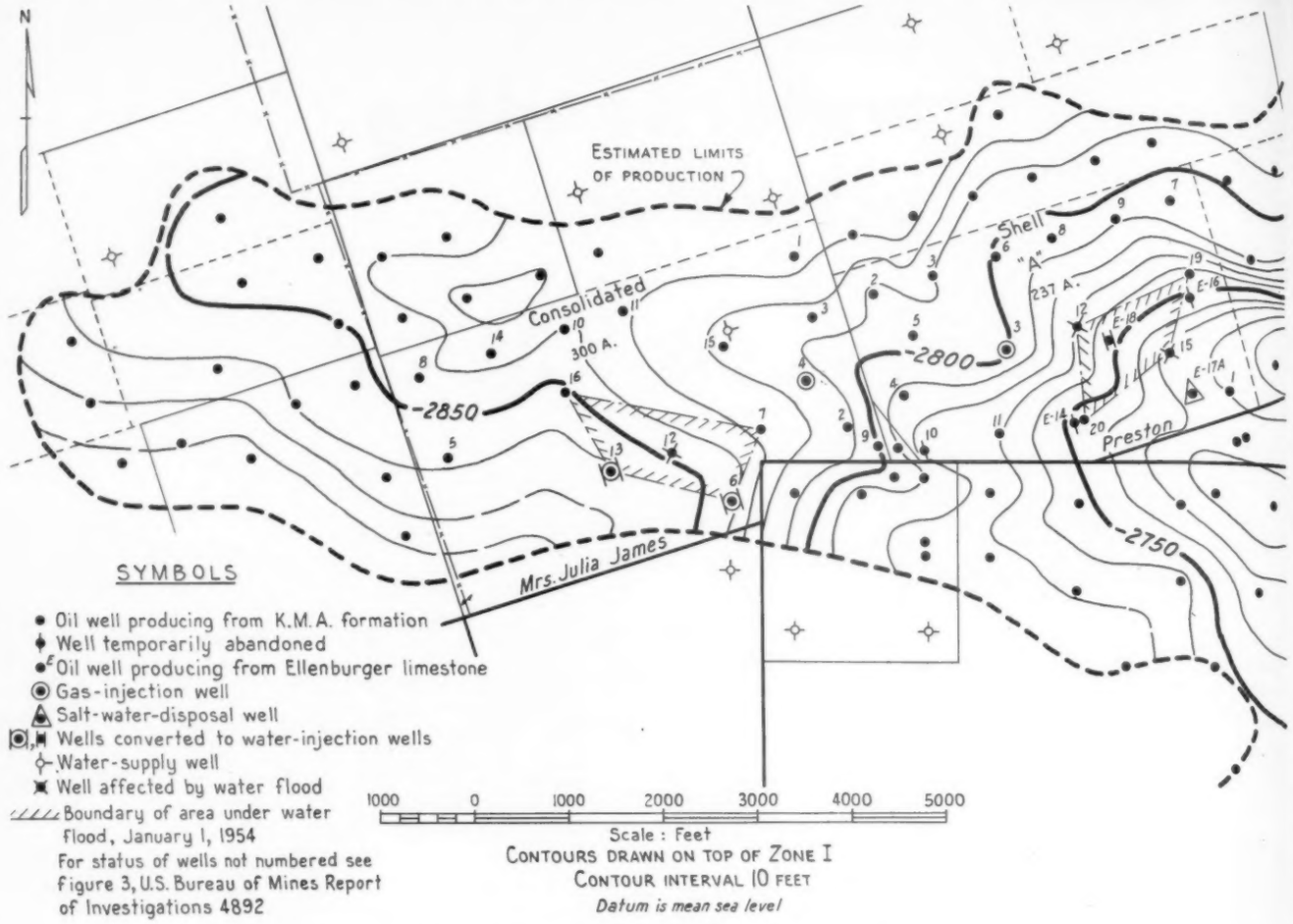


FIG. 22. Structure map of Zone I, part of Unit 6

A chemical analysis of the injection water is as follows:

Radical	Ppm
Calcium (Ca)	17,460
Magnesium (Mg)	2,510
Sodium (Na)	59,390
Silica (Si)	0
Iron (Fe)	0
Bicarbonate (HCO_3)	85
Sulfate (SO_4)	160
Chloride (Cl)	129,255
Total solids	209,255

Specific gravity, 1.1477

Results of Waterflooding

The net oil recovered as a result of flooding to January 1, 1952, was an estimated 1950 bbl or 92.9 bbl per flood-pattern acre. The pilot flood was initiated to determine if the reservoir oil could be moved successfully by injected water and the wellhead pressure necessary to inject the water.

After it was concluded that the KMA Zone I reservoir could be successfully waterflooded, the pilot flood was discontinued December 20, 1951. A larger waterflooding program is being planned for the lease and for the other leases in Unit 6, KMA field.

Pertinent data on the project before and during waterflooding are given in Table 1.

Consolidated Oil Company James Project

This waterflooding project is in the H. & T. C. RR. Company survey, block 7, sec 16, and is approximately 4000 ft west of the Shell Oil Company Preston "A" flood. Water injection was begun during July, 1952.

History Before Waterflooding

The Consolidated Oil Company pilot waterflood is on the Julia James lease, which covers 279 productive acres. The gross reservoir volume of Zone I (the zone being flooded) is 13,573 acre-ft, and the zone will average 48.6 ft in gross thickness. The cumulative oil production to July, 1952, at the time waterflooding was begun, was 992,149 bbl or 3556 bbl per acre. The average daily oil production for the lease was approximately 55 bbl at that time.

Structure maps contoured on top of Zones I and II (Fig. 22 and 23) show the subsurface configuration of the two zones in this area. Isopachous maps showing the gross thickness of Zones I and II are depicted as Fig. 24.

Development of the lease was begun in August, 1938, and completed during July, 1941, except for well No. 16, which was completed in December, 1950. All but one of the producing wells was completed with 7-in. casing set and cemented between the top of the KMA limestone and the top of Zone I; well No. 15 was completed with 5½-in. casing. Zone II is not open to the well bore in any of the producing wells.

Except for wells No. 2 and 5, all have been shot with nitroglycerin.

Gas injection into the reservoir was begun in March, 1940, when gas was injected into well No. 4. Well No. 13 was converted to a gas-input well in October, 1942, and well No. 6 in May, 1948. Except for a short period during the latter part of 1946 and early part of 1947, these wells have been active gas-input wells.

The initial input pressure varied from 800 to 1500 psi and during June, 1952, was approximately 600 psi. The gas-input volumes during June, 1952, were approximately 50, 50, and 40 Mcf per day for wells No. 4, 6, and 13, respectively. Gas injection into well No. 4 was discontinued in May, 1953.

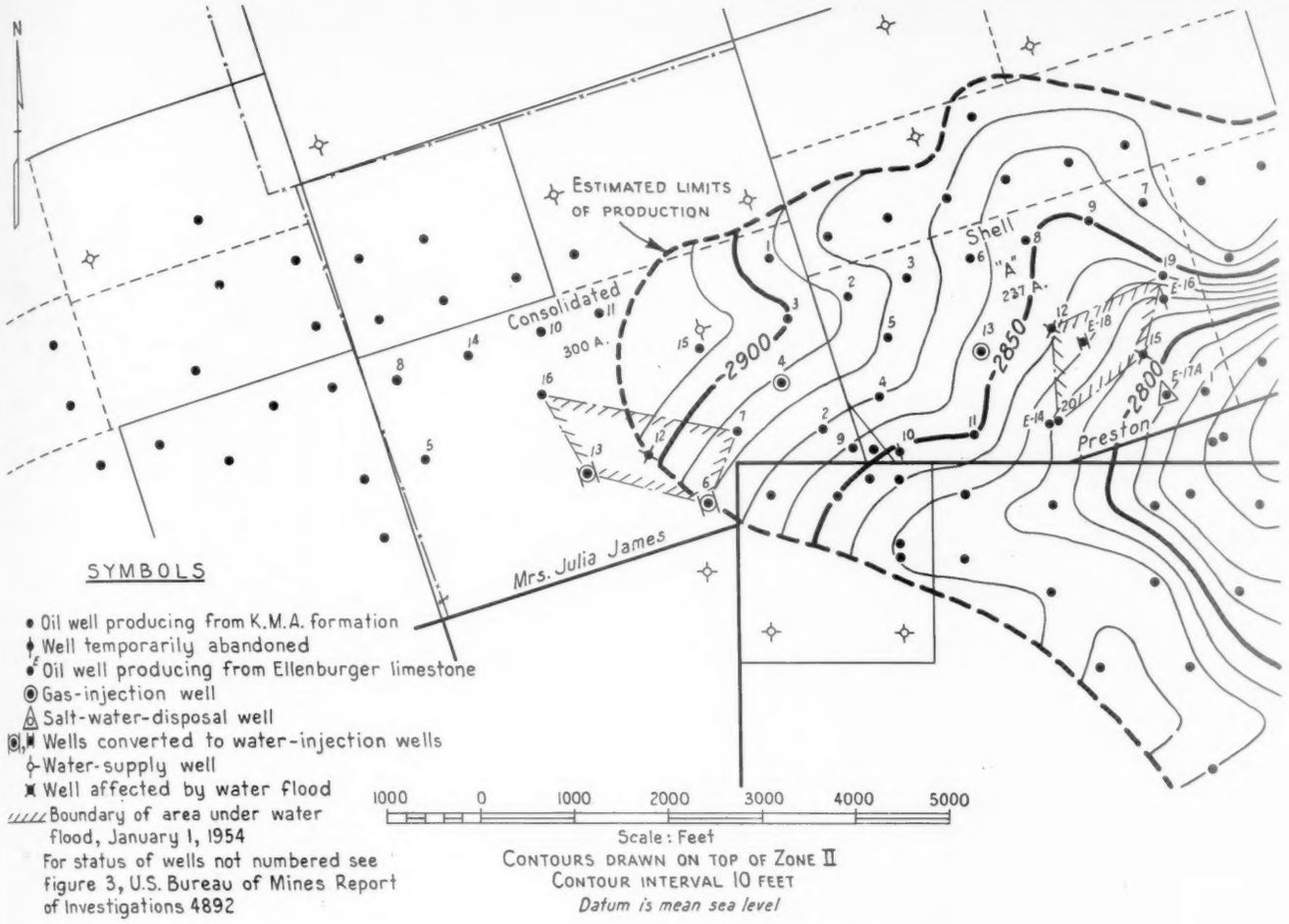


FIG. 23. Structure map of Zone II, part of Unit 6

Development of Waterflood

Water injection into Zone I was begun when gas-input wells No. 6 and 13 were converted to water-input wells in July, 1952.

The flood-pattern area, as outlined in Fig. 22 and 23 includes producing wells No. 7, 12, and 16. The area of the flood pattern is 29.4 acres. Zone I has a gross reservoir volume of 1355 acre-ft and averages 46.1 ft in gross thickness.

At the start of the flood, water was injected at a rate of approximately 220 bbl per day into each of the two injection wells at a wellhead pressure of 60 to 130 psi. During December, 1953, the injection rate was approximately 320 bbl per day in each of the two injection wells at a wellhead pressure of 50 to 100 psi. The pressure required to inject the water is supplied by the casing pump in the water-supply well. The input wells do not have tubing in the hole. To January 1, 1954, an overall average of 8.7 bbl water per day per injection well per ft of gross sand thickness had been injected.

TABLE 4. Analyses of core sections from zone 1, KMA formation, KMA field, Wichita and Archer counties, Texas, Gulf Oil Corp., Ferguson-Buffalo well No. 23 and Gulf Oil Corp., Ferguson-Howell well No. 33.

Well No.	Core from which section was taken, number	Interval from which core was taken, ft. below derrick floor		Average horizontal permeability, millidarcys	Ratio min. to max. horizontal permeability, per cent	Angle between max. and min. horizontal permeability axes	
		From	To			Degrees	Quadrants
23	2	3700	3701	36.46	86.6	90	—
23	4	3703	3704	25.05	31.4	60	2d & 4th
23	5	3704	3705	.116	15.9	30	2d & 4th
23	20	3712	3713	.062	71.1	90	—
23	6	3714	3715	23.94	90.2	90	—
23	7	3725	3726	.177	57.6	90	—
23	8	3726	3727	13.46	81.2	90	—
23	9	3728	3729	10.59	49.2	60	1st & 3d
23	10	3730	3731	13.10	69.1	90	—
23	11	3731	3732	.292	75.7	90	—
23	12	3736	3737	13.51	86.6	60	1st & 3d
23	13	3737	3738	7.59	79.3	30	2d & 4th
23	15	3741	3742	42.56	82.3	90	—
23	16	3742	3743	.473	80.3	60	1st & 3d
Summary, 14 core sections		3700	3743	13.31	71.7	85.7	2d & 4th
33	1	3706	3707	0.251	53.4	60	2d & 4th
33	2	3707	3708	.183	81.2	90	—
33	3	3708	3709	54.82	87.5	30	2d & 4th
33	6	3730	3731	33.09	71.5	90	—
33	7	3731	3732	76.97	77.3	60	1st & 3rd
33	8	3732	3733	.130	75.0	90	—
33	9	3733	3734	23.04	80.0	60	1st & 3d
33	11	3735	3736	44.11	76.4	90	—
33	12	3736	3737	.168	42.7	60	1st & 3d
33	13	3737	3738	75.24	85.1	30	1st & 3d
Summary, 10 core sections		3706	3738	30.80	80.2	84	1st & 3d
Summary, 24 core sections		3700	3743	20.60	76.9	90	
Summary, 15 core sections				Greater than 1 millidarcy	77.0	88	1st & 3d
Summary, 9 core sections				Less than 1 millidarcy	61.9	86.7	2d & 4th

Method of Completing and Operating Wells

No input wells were recompleted when they were converted for water injection. Casing is set 16 ft above the top of Zone I in well No. 6 and at the top of Zone I in well No. 13. Five feet of shale below. Zone I is open to the

well bore in well No. 6. The tubing was removed from the gas-input wells when they were converted to water-injection wells.

No remedial work was done on the producing wells when water injection was begun. They are pumped by standard surface jacks powered by gas engines and standard subsurface plunger-type pumps. The injection wells are equipped with a pressure gauge at the wellhead, a value to shut off the injection water, and a backflow drain line.

Source of Treatment of Injection Water

The brine used for injection is obtained from a water-supply well producing from a Cisco series sandstone. The well was drilled to a total depth of 1128 ft and equipped with 7-in. casing set at 1090 ft. The supply well is pumped with a 3¾-in. by 12-ft Lantex casing pump set close to the bottom of the hole.

The injection water is not treated and is pumped directly from the water-supply well through 2-in. tubing to the meter manifold and then to the input wells. The injection rate is regulated by chokes at the meter manifold.

An analysis of the chemical constituents of the injection water follows:

Radical	Ppm
Sodium (Na)	54,892
Calcium (Ca)	14,556
Magnesium (Mg)	381
Soluble silica (SiO_2)	12.0
Hydrogen sulfide (H_2S)	0.75
Free carbon dioxide	80.0
Turbidity	120
Supersaturation in bicarbonates as calcium carbonate	0
Chloride (Cl)	111,000
Sulfate (SO_4)	864
Bicarbonate (HCO_3)	49
Barium (Ba)	0
Dissolved iron (Fe)	15.0
Total iron (Fe)	17.5
Dissolved solids	181,762
Total solids	181,882

Indicated pH, 5.9
Specific gravity, 1.12 at 24° C.

Results of Waterflooding

A total of 315,171 bbl of water had been injected to January 1, 1954, without an increase in oil production. A small increase in oil production from well No. 12 was noted during the early part of January, 1954, which may indicate that the injected water is beginning to move the reservoir oil. If the pilot flood responds successfully, the operator plans to develop the lease with a line-drive type of pattern, using input wells along the southwestern edge of the lease and flooding updip.

Pertinent data of the project before and during waterflooding are given in Table 1.

Results of Directional Permeability Tests

The production statistics for individual wells in some KMA waterflooding projects indicate that the movement of injected water from input wells to producing wells is more linear than radial. The directional permeability of the reservoir rock could be one of several factors that would cause linear flow of fluids in the KMA reservoir.

To determine the possible existence and magnitude of directional permeability, a study was made of the horizontal permeability measurements of core plugs taken at 30 deg radial intervals around the circumference of the core and in the same horizontal plane. Cores from Zone I of the KMA formation from Gulf Oil Corporation Ferguson-Buffalo well No. 23 and the Gulf Oil Corporation Ferguson-Howell No. 33 were used for the permeability tests. Air-permeability measurements were recorded on core samples taken at 24 different levels along the two cores. The results of these tests are summarized in Table 4.

The directional permeability data indicate that a definite trend of maximum horizontal permeability exists across core section and that the trend generally is at right angles to the trend of minimum horizontal permeability. The permeability measurements at the 24 different levels in the two cores reveal that the maximum permeability exceeds the minimum permeability at an approximate ratio of 4:3 in a horizontal plane.

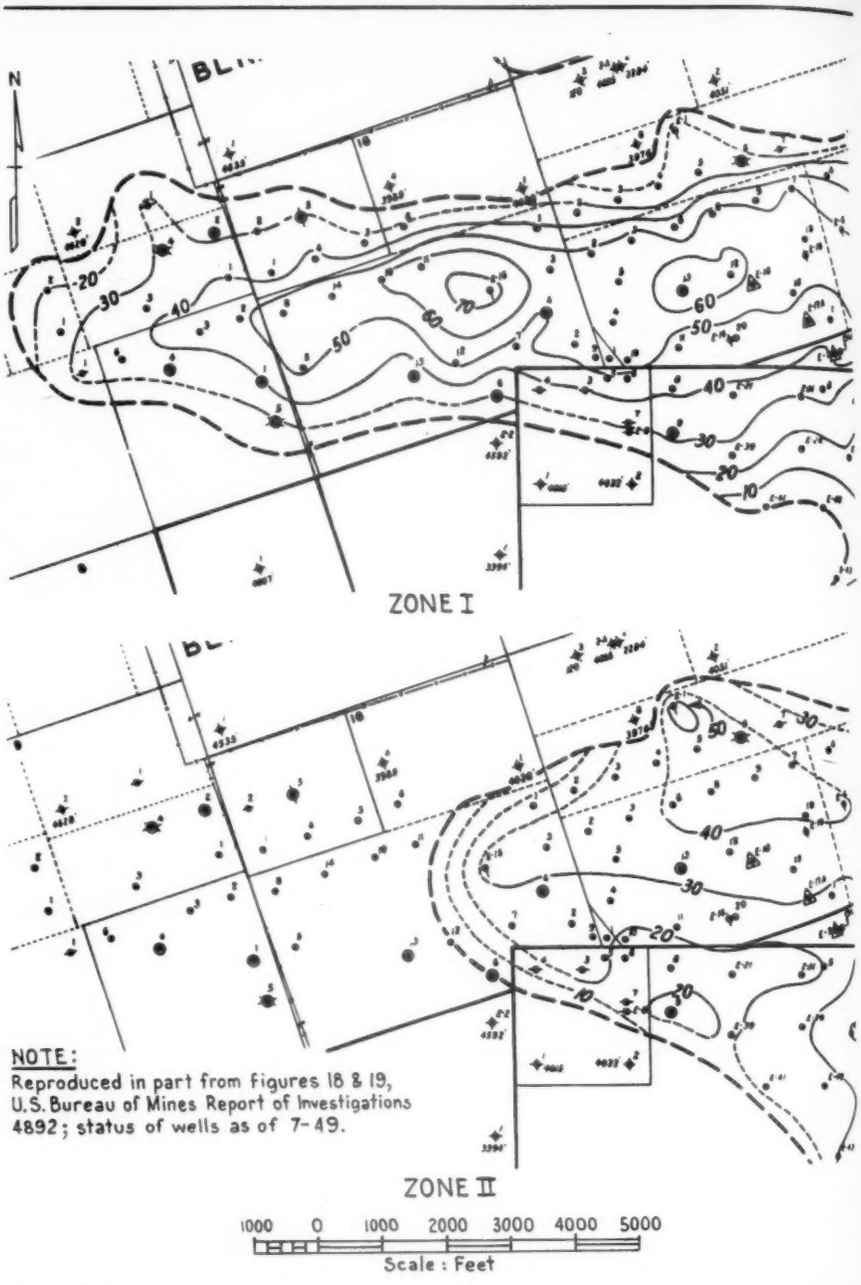
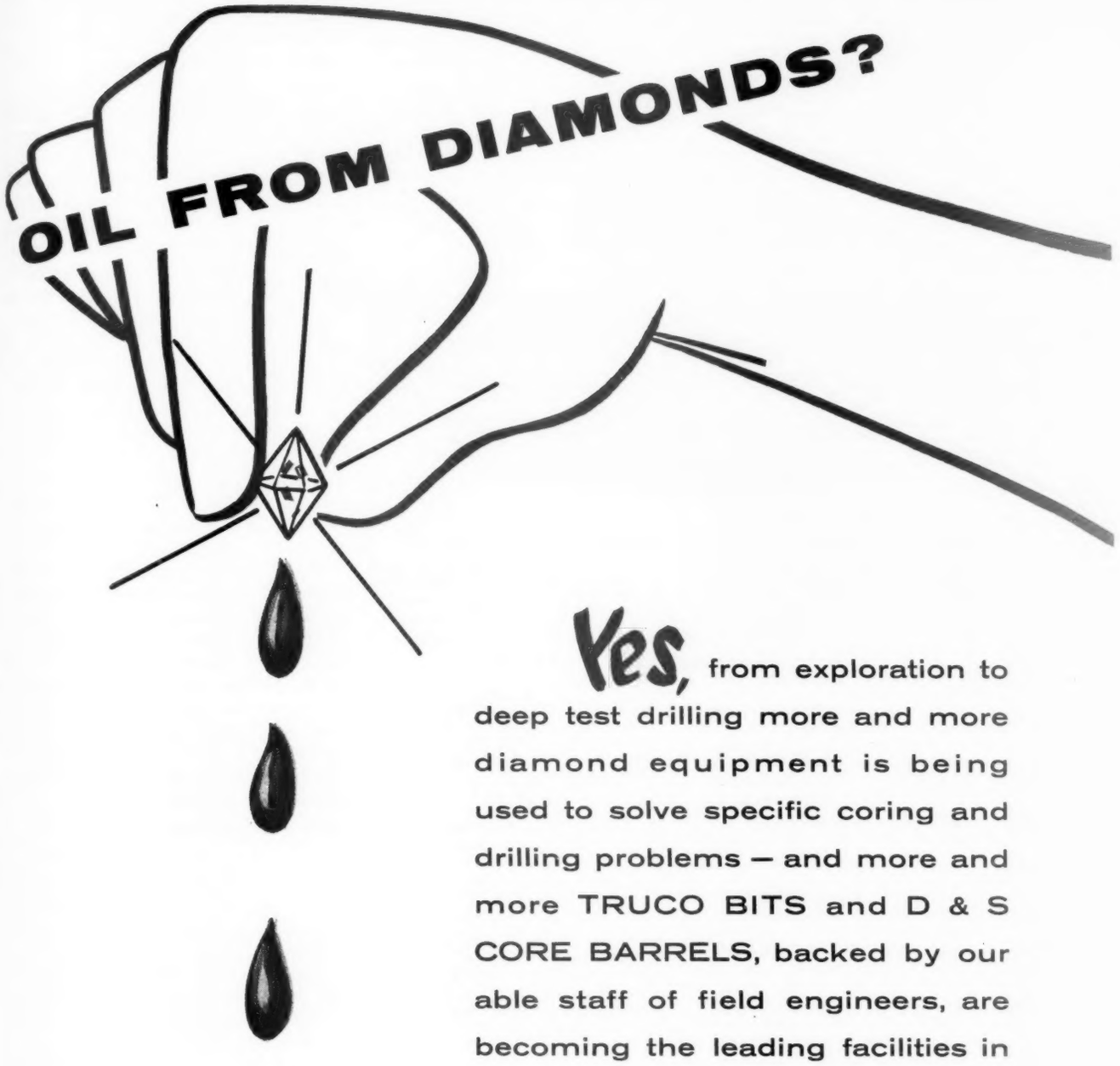

N
ZONE I
ZONE II
NOTE:
Reproduced in part from figures 18 & 19, U.S. Bureau of Mines Report of Investigations 4892; status of wells as of 7-49.
1000 0 1000 2000 3000 4000 5000
Scale : Feet

FIG. 24. Isopachous map showing gross thickness of Zones I and II in part of Unit 6

OIL FROM DIAMONDS?



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This ratio between maximum and minimum permeability is not as high as might be expected from observing the movement of fluids in the KMA reservoir. Further study on cores coupled with a detailed study of the movement of fluids within the reservoir is warranted. If directional permeability is a predominant influence in the movement of fluid in the KMA reservoir, the injection wells should be spaced to provide the most efficient flood pattern.

Conclusion

Although waterflooding in the KMA field is still in its infancy, the active and abandoned waterfloods, both succesful and unsuccessful,, have definitely proved that oil can be moved through the reservoir by the injection of water.

A study of waterfloods in this report indicates that the operators who are flooding Zone II in the southwestern part of the field have encountered production problems that must be overcome before this zone can be economically flooded. High produced water-oil ratios early in the life of the floods, caused by injection water bypassing either through streaks of very high permeability (1500 to 2500 md) or through oil-barren sections of rock open to the well bore in the injection wells, must be reduced before Zone II can be flooded successfully. This area should not be condemned until one or more comprehensive pattern-type pilot floods have been tried.

All waterfloods in Zone I have not shown a favorable response. It is believed, however, that the results obtained by waterflooding this zone can be improved if the operators will complete their injection wells so that the injected water will be confined to Zone I, consider the structural features of the formation when designing the flood pattern, and balance the injected water either volumetrically or by pressures.[2]

The fact that the two pilot floods in Unit 3 are being expanded into one, which will cover over 3000 acres, is good evidence that the operators believe the KMA reservoir in the area can be successfully waterflooded.

Prolonged operation of floods in a pilot stage, regardless of the results obtained, may have harmful effects on the volume of oil that can be recovered by an expanded program. If the results obtained within a reasonable time are not favorable, either the trouble should be ascertained and remedied or the injection of water temporarily discontinued until a decision can be reached regarding the future status of the project. If the results obtained are favorable, the flood should be expanded into full-scale operation or the injection of water should be discontinued until the expanded program can be placed in operation.

Acknowledgments

This report was prepared at the request of the North Texas Section of the AIME and the Production Committee of the North Texas Oil and Gas Association.

The part of the report prepared by the Bureau of Mines was done under a cooperative agreement with the North Texas Oil and Gas Association.

The writers sincerely appreciate the fine cooperation of the executives, engineers, and the field personnel of all of the oil companies and operators waterflooding in the KMA field in generously supplying the data, information, and assistance requested for this report.

The writers also acknowledge the assistance of the following members of the Bureau of Mines: K. F. Anderson, C. J. Wilhelm, E. L. Comer, J. M. Seward, W. C. Elliott, Jr., Paul Meadows, and M. E. Hawkins.

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Donnell Drilling Company's Rig No. 10, which drilled a recent Spraberry well for the Hanley Company in 14 days, 16 hours.

P 425.26

Contractor-Operator Teamwork . . .

Cuts Spraberry Drilling Time

Donnell Drilling Company of Odessa, Texas, Finishes Well in 14 days, 16 Hours.

MANY people think of the Spraberry Trend as a "dead" area as far as drilling activity is concerned. And, it is far different now than it was in the spring of 1952, when more than 200 rigs were at work in the area. More than 20 rigs, however, have been at work in the trend throughout the last two years, and activity continues lively. Many drilling contractors have steered clear of work in the Spraberry since the footage price now is approximately ⅔ of the standard $6.00 per foot, which prevailed during "the boom."

That a drilling contractor can operate profitably now in the Spraberry is illustrated by the performance of Donnell Drilling Company's Rig No. 10, working on the Aldwell Lease for the Hanley Company. This rig has just completed its fifth well for the Hanley Company, the Aldwell A-2, in 14 days, 16 hours. This is no "one-shot" record-breaking attempt; the previous well, the Aldwell B-1, was drilled in 14 days, 18½ hours. None of the five wells have taken more than 18 days.

When this drilling performance is compared with the usual 25 to 35 days required to drill a lower Spraberry well during the boom, there is "something extra" that has been responsible. That "something extra" is the cooperation and understanding of the Hanley Company personnel, planning and working with the Donnell men. This teamwork was apparent from the time the rig moved onto the lease for its first well.

The operator furnished a water well and line pipe for the water line. The contractor's crews laid the water line. The water well was drilled in a central location on the lease, and a lease tank battery was erected nearby. After each well is completed, the water line is left in place and becomes the flow line for the producing well.

Everything possible is done to reduce the time on location for the drilling rig. Before the rig is skidded onto a new location, the surface hole has been drilled and 350-ft of 9⅝-in. spiral-weld casing has been set by a cable tool rig. Cement has been circulated on this surface pipe. A rathole and mouse hole have been dug by a small "shot hole" rig, and the mud pits have been dug and filled with water. An extra 500 bbl tank on the new location also is filled with water. The rig is skidded on location with the kelly in the derrick and the rathole and mousehole casing standing in the derrick. Once the rig is spotted and pump is skidded in and belted, drilling operations can proceed at once.

Drilling Rig. Donnell's Rig No. 10 is powered by two 360-hp gas engines. The mud pump is a 450-hp, 8 by 16-in. unit and is driven off the drawworks power compound. A double gate blow out preventer with hydraulic controls is used. A 131-ft, 625,000-lb jackknife derrick completes the major surface equipment list. Four inch OD drill pipe with 4-in. hardened tool joints is used above twenty 6-in. OD drill collars with 2¼-in. bore.

In drilling the 7⅞-in. hole from 350 ft to 7700 ft., thirty rock bits were used. The first six of these, to 4280 ft, were jet bits. Nine hundred psi pump pressure was used with the jet bits.

Mud Program. Drilling out from under the surface pipe, clear water was used as the drilling fluid to a depth of 4000 or 4500 ft. Circulation was through the reserve pit while drilling with clear water; when starting to mud up, circulation was through the mud pits. As the mud was mixed, crude oil

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was added through a ¼-in. choke nipple in the mud pump suction. No emulsifying agent was used, and crude oil was added continuously as drilling progressed. A total of 995 bbl of oil was used on the Aldwell B-1.

The mud was made up on a salt-gel base with fibertex, and cotton seed hulls added. Viscosity was maintained at 34 increasing to 40 as required. Mud weight was 9.7 lb per gallon when first mixed and was reduced to 9.1 lb per gallon as the producing zone was approached. Hanley made no requirement on the drilling contractor regarding mud quality, viscosity, or water loss.

Cementing Practice. The Hanley Company's cooperation to reduce lost rig time is further illustrated when the 5½-in. casing was run. The casing string was made up of 7700 ft of 5½-in. casing (66 joints of J-55 15.50 lb, 115 joints J-55 14.00 lb, 63 joints of J-55 15.50 lb.) In cementing, the following materials were added in the order given: 10 sacks Posmix, 3 sacks Signalite, 3 sacks lime, 10 sacks Posmix, 3 sacks Signalite, 125 sacks cement 2 per cent gel, 250 gal mud acid on plug. Plug was pumped down with oil.

Once the casing string was run, pipe was set on the braden head and the cement head was set under the floor. While the cementing company was mixing cement and pumping the plug down, the drilling crew was tearing down preparing to skid. Actually, the rig was released once the pipe was set on the braden head, and the cementing head was in place. The rig was skidded on to the next location, where surface hole had been dug, pipe set and cemented, rathole and mousehole dug, pits and water tank in place and filled with water. Everything was set too start drilling again! On the move from the Aldwell B-1 to the Aldwell A-2 (about ½ mile skid move) only 10 hours were required to skid, rig up, and start drilling. The following schedule tells the story:

ALDWELL B-1

Drilled Plug—11:00 P.M.—5-21-55
Total Depth 7700 ft—5:30 P.M.—6-4-55.

13 Days	18½	hr drilling time
	6½	hr circulating, laying down pipe and drill collars
	7½	hr running casing, mixing cement, and pumping down plug
	10	hr skid and rig up and begin to drill plug
14 Days	18½	hr

Fast Time—Yes! And it can be done when producing company and contractor cooperate to minimize problems. * * *

PERSONNEL ON A DRILLING RIG

Gene Graham*

THE personnel on an oil well drilling rig consists of a group of operators who have certain skills and functions which are uniform in the business of drilling a well, and they will be described below. These operators are artisans of a sort who ply their trade as do carpenters, bricklayers, etc., not caring so much for whom they work as they do for the opportunity to work on a rig.

A drilling rig operates 7 days a week, 24 hours a day, and a full staff must be on the job at all times in order that the rhythmical teamwork-type of operation may be accomplished without delays. Drilling rigs are generally staffed, for a tour (pronounced "tower") or shift, by a crew of 4 or 5 men. Four man crews are used on the small shallow drilling rigs, and 5 man crews are used on the larger rigs.

Each 5 man drilling crew consists of a driller, a derrickman, a catheadman, and two floormen (rotary helpers).

The Driller

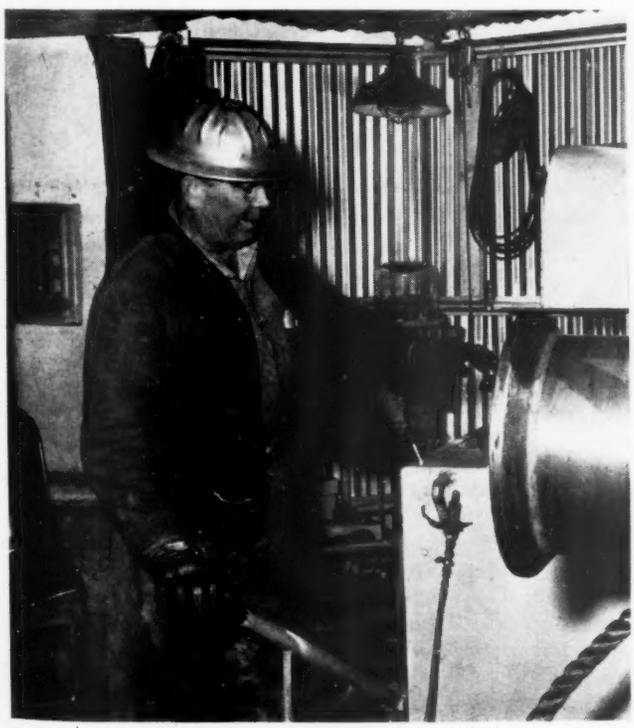
The driller is in charge of his crew, and in charge of the rig's operations during his tour. He reports to a foreman who is usually called a "toolpusher."

In his position as boss of the rig and the crew, the driller must be responsible for safe, economical operations at all times. He always has a background of experience in performing the jobs of those men working under him; he knows thir problems and what is required of them by having done this work himself. The relationship between the driller and his crewmen is such that the driller will often take his crew with him when he changes jobs.

Good judgment and alert attention to detail are probably the two prime requisites of a driller. They are necessary to safeguard the lives of his fellow workers and to protect the huge investment of his employer.

Specifically, it is the driller's function to operate the drawworks in the hoisting of the drilling string (drill-pipe and tools) from the hole and in running it back into the hole, as well as to maintain the proper characteristics of the machinery while drilling with a bit on bottom. The weight on the bit, the speed of the rotary table, the pressure and volume of the mud circulating fluid and are some of these characteristics.

*Executive Vice President, Thomas P. Pike Drilling Co., Los Angeles, California.



The driller operates the drawworks.

The derrickman tests the drilling fluid.

The Derrickman

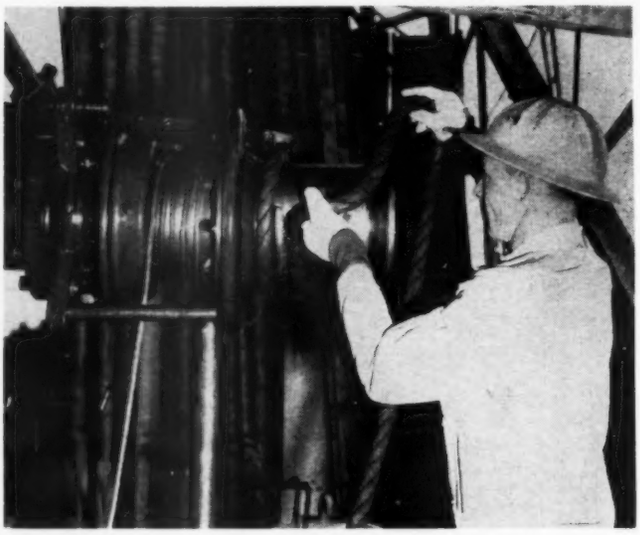
The derrickman works high in the derrick or mast while "making a trip," that is, when the pipe is being hoisted from the hole or run back on bottom. Stationed on the derrick platform known as the "monkey board," which is 90 ft above the derrick floor, it is his function among others to seize the upper end of the 90-ft stand of pipe as it comes out of the hole and pull it over into the rack.

He also tests the circulating fluid to maintain its properties in accordance with the mud program specified for the well. It is his responsibility to assure the proper functioning of the mud pumps; to check their operation frequently; to replace worn parts, and to provide the pump's efficient operation at all times.

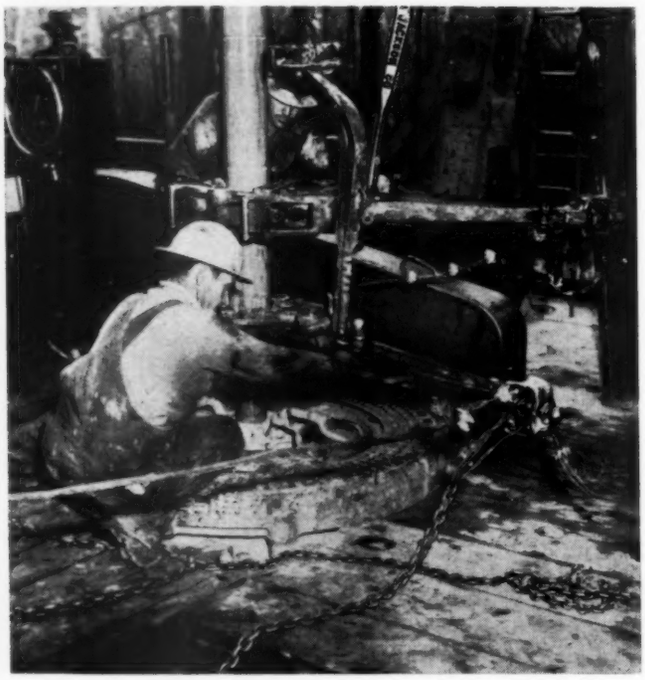
The Catheadman

The term catheadman is applied to the third ranking member of the drilling crew. Some contractors term this man a motorman. He is usually more experienced in all phases of the work than the rotary helpers.

His job is to operate the manual catheads on the draw-



The catheadman is sometimes called motorman.



Rotary helpers operate the tongs.

works whenever they are used and to supervise service of the motors and engines for uninterrupted operation. It is he who adds oil when needed, supervises the oil changes, watches the radiator water and generally performs the function of a serviceman with respect to the motors.

Rotary Helpers

The two rotary helpers are the tong operators during a trip. It is their job to see that the tongs are placed properly on the drilling string, to rack the pipe and to be ready for the next similar operations in rhythm with the machinery as operated by the driller. When the bit is on bottom drilling there are 101 miscellaneous duties for the rotary helper to perform.

Maintaining the rig's housekeeping is a large order in itself—straightening up the floor; picking up numerous pieces of equipment; cleaning and painting the machinery; helping the motorman with the engines; helping the derrickman with the mud treatment, etc.

It was stated earlier that the large rigs have 5 man crews and the smaller rigs 4 man crews. The usual difference is that there is one less rotary helper or floorman on a 4 man crew rig.

The Foreman or Toolpusher

The toolpusher is actually the manager of his branch of his company's operation. During the drilling of the well he must be available at any time day or night for consultation with the drillers. He is the Management of the drilling company insofar as his crews are concerned. In today's fast moving contract drilling economy, the toolpusher must have at least a smattering of knowledge on labor laws, personnel relationships, of chemistry (for mud control), hydraulics (for circulating fluid), internal combustion engines, etc., etc. He is the key man in any drilling contractor's organization. He usually has authority to spend money to keep his rig in operation, cooperating, of course, with his spervisor on any items of major importance. Since he does not drill a foot of hole himself, it could be said that his prime function is to assist the drillers and their crews to drill the hole safely, economically and promptly.

The foreman makes his headquarters in an office at the rig known as the "doghouse," where he must keep accurate records of daily drilling, performance, purchases of materials, accident reports, and other paperwork which must go daily to the main office for coordinating with the other company accounting and records. Here he also interviews salesmen from the supply houses, consults with the production superintendent and other personnel from the producing company and is available by telephone to the outside world which may be many miles away. When he leaves the rig, he usualy is still in touch by mobile telephone.

The foreman's responsibilities cover every operation of the rig including clearing and staking out the drillsite, moving in the rig, and rigging up and tearing it down when the job is finished.

Drilling Superintendent and Assistant

Depending upon the size of a contracting organization, there may be an assistant drilling superintendent as well as a drilling superintendent. Again, it is the function of these men primarily to aid the toolpusher in the conduct of their work. The drilling superintendent usually has authority to authorize the expenditure of larger sums of money than do the toolpushers. Usually there is a limit placed by top management on the amounts that any foreman of whatever rank may spend without top management's approval.

* * * * *

These are the duties of the principal field personnel on a drilling rig. Behind them in the administrative end of the business, an office force must be maintained to solicit business, contact clients, estimate for bids, maintain an equipment yard and repair shop and figure what the company has left after taxes.

This type of personnel is much the same as in any other type of contracting business. In oil well drilling, the walls of the general manager's office are covered with maps showing the locatoin of each company rig, and with charts and graphs which show the daily drilling progress on each job, with the normal curve of the estimate beside it for constant comparison.

A fishing job, a bad accident, or even an unexpected zone of tough going may cause the performance curve to fall away sharply from that laid out in the estimate, but that's the nature of the business. A drilling contractor has to be prepared to weather runs of hard going as part of normal business expectations. To weather these low spots successfully, he needs the kind of field men and teamwork which can make up for losses by drilling more hole at less cost when the going is according to estimate.

INSTRUMENTS

Karl L. Kellogg*

FOR the purpose of this chapter, only those drilling instruments used in the actual drilling operation will be discussed. Instruments applied to testing and well completion are covered in other chapters. As a general classification the drilling control instruments are those that give a continuous indication of the variables under the control of the driller, and whose proper interpretation can give the greatest degree of control over the rate of penetration, hole deflection and bit life.

The art of oil well drilling is fast becoming, like other purely mechanical operations, a science of reading, correlating and interpreting the information available through the use of sensitive, relatively fool-proof instruments. "Drilling by the seat of one's pants," once an expression about as commonly used as "flying by the seat of one's pants," is now about as obsolete in the art of rotary drilling as the latter is in the flying profession. Much technological advancement has been made in the instrumentation of oil well drilling and considerably more is anticipated or is in the development stages.

The main control instruments are the weight indicator, mud pressure and volume instruments, rotary torque gage and tachometer. The *application* of these instruments and the *interpretation* of the data obtained therefrom is an art that must be learned and effectively applied by the driller if maximum efficiency is to be obtained in rotary drilling.

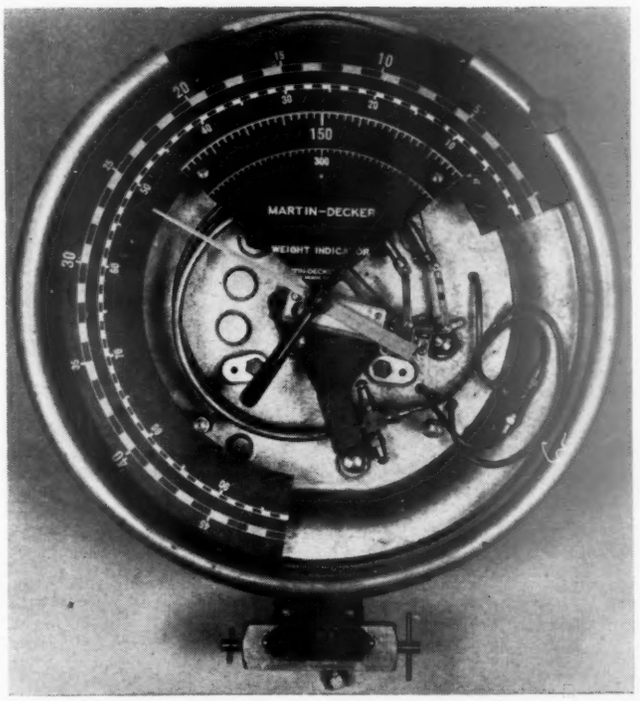


FIG. 1. Cutaway of a typical gage. The pressure transformer develops the hydraulic pressure per square inch throughout the whole system. It is transmitted uniformly through the copper tubing at right and into the C-shaped Bourdon tubes, effecting a straightening action and causing the linkage on the tube tips to pull the quadrant levers. These, in turn, rotate the gears to which pointers are attached.

Weight Indicator

The weight indicator is the primary drilling control instrument. It is used to control the weight that is applied to

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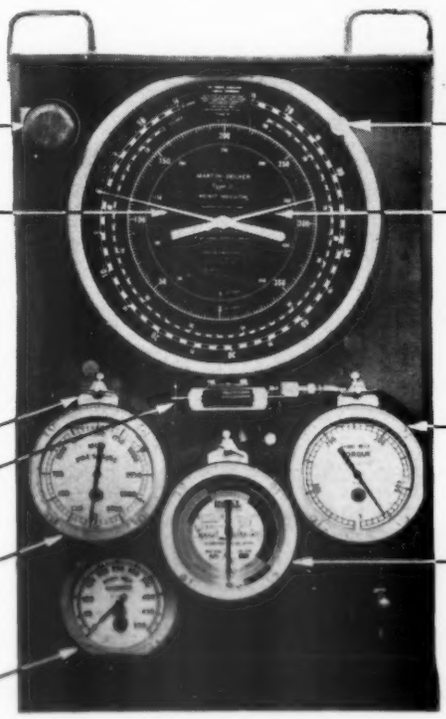
Vapor-proof light for safe illumination around combustibles.
Red hand shows the net-weight-on-bit on outer dial, and serves as a vernier on inner dial for fishing, milling, cutting, etc.
All hydraulic gauges have manually operated dampers for controlling pointer fluctuations.
Mud-pump-pressure gauge at driller's position immediately warns of pressure changes.
Tachometer shows actual RPM of rotary table.
Knurled knob for setting outer dial on zero with bit off bottom. Net weight placed on bit is then read directly.
Yellow hand indicates hook load at all times (on inner dial)—showing tight hole, stuck pipe, etc.
Torque gauge indicates bit conditions, and warns of dangerous excess torque.
Drawworks speed selector shows driller what gears to use for optimum hoisting speeds without overloading.

FIG. 2. These instruments, grouped for driller's convenience and to expedite moving, take the guesswork out of modern drilling.

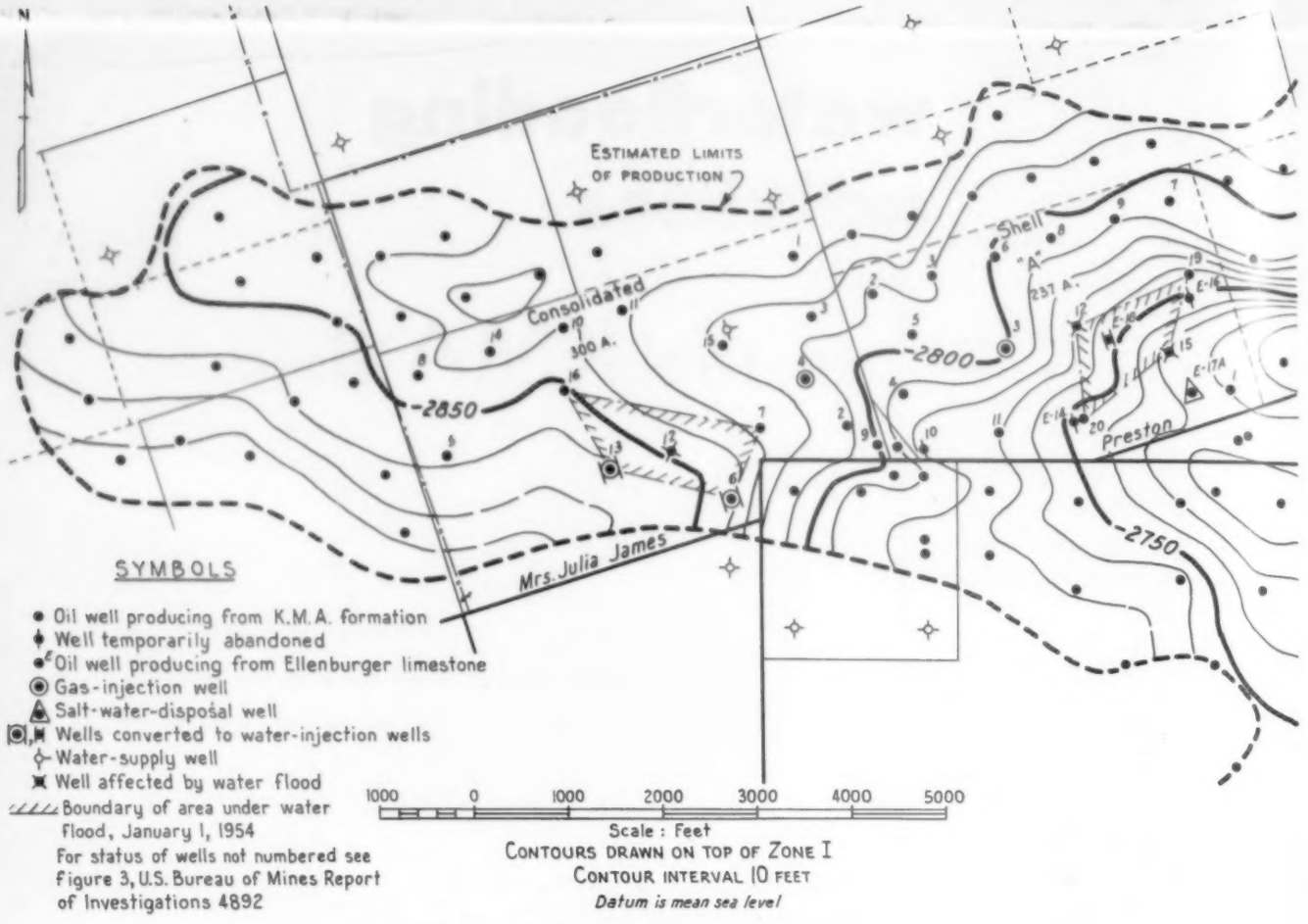

FIG. 22. Structure map of Zone I, part of Unit 6

A chemical analysis of the injection water is as follows:

Radical	Ppm
Calcium (Ca)	17,460
Magnesium (Mg)	2,510
Sodium (Na)	59,390
Silica (Si)	0
Iron (Fe)	0
Bicarbonate (HCO_3)	85
Sulfate (SO_4)	160
Chloride (Cl)	129,255
Total solids	209,255

Specific gravity, 1.1477

Results of Waterflooding

The net oil recovered as a result of flooding to January 1, 1952, was an estimated 1950 bbl or 92.9 bbl per flood-pattern acre. The pilot flood was initiated to determine if the reservoir oil could be moved successfully by injected water and the wellhead pressure necessary to inject the water.

After it was concluded that the KMA Zone I reservoir could be successfully waterflooded, the pilot flood was discontinued December 20, 1951. A larger waterflooding program is being planned for the lease and for the other leases in Unit 6, KMA field.

Pertinent data on the project before and during waterflooding are given in Table 1.

Consolidated Oil Company James Project

This waterflooding project is in the H. & T. C. RR. Company survey, block 7, sec 16, and is approximately 4000 ft west of the Shell Oil Company Preston "A" flood. Water injection was begun during July, 1952.

History Before Waterflooding

The Consolidated Oil Company pilot waterflood is on the Julia James lease, which covers 279 productive acres. The gross reservoir volume of Zone I (the zone being flooded) is 13,573 acre-ft, and the zone will average 48.6 ft in gross thickness. The cumulative oil production to July, 1952, at the time waterflooding was begun, was 992,149 bbl or 3556 bbl per acre. The average daily oil production for the lease was approximately 55 bbl at that time.

Structure maps contoured on top of Zones I and II (Fig. 22 and 23) show the subsurface configuration of the two zones in this area. Isopachous maps showing the gross thickness of Zones I and II are depicted as Fig. 24.

Development of the lease was begun in August, 1938, and completed during July, 1941, except for well No. 16, which was completed in December, 1950. All but one of the producing wells was completed with 7-in. casing set and cemented between the top of the KMA limestone and the top of Zone I; well No. 15 was completed with 5½-in. casing. Zone II is not open to the well bore in any of the producing wells.

Except for wells No. 2 and 5, all have been shot with nitroglycerin.

Gas injection into the reservoir was begun in March, 1940, when gas was injected into well No. 4. Well No. 13 was converted to a gas-input well in October, 1942, and well No. 6 in May, 1948. Except for a short period during the latter part of 1946 and early part of 1947, these wells have been active gas-input wells.

The initial input pressure varied from 800 to 1500 psi and during June, 1952, was approximately 600 psi. The gas-input volumes during June, 1952, were approximately 50, 50, and 40 Mcf per day for wells No. 4, 6, and 13, respectively. Gas injection into well No. 4 was discontinued in May, 1953.

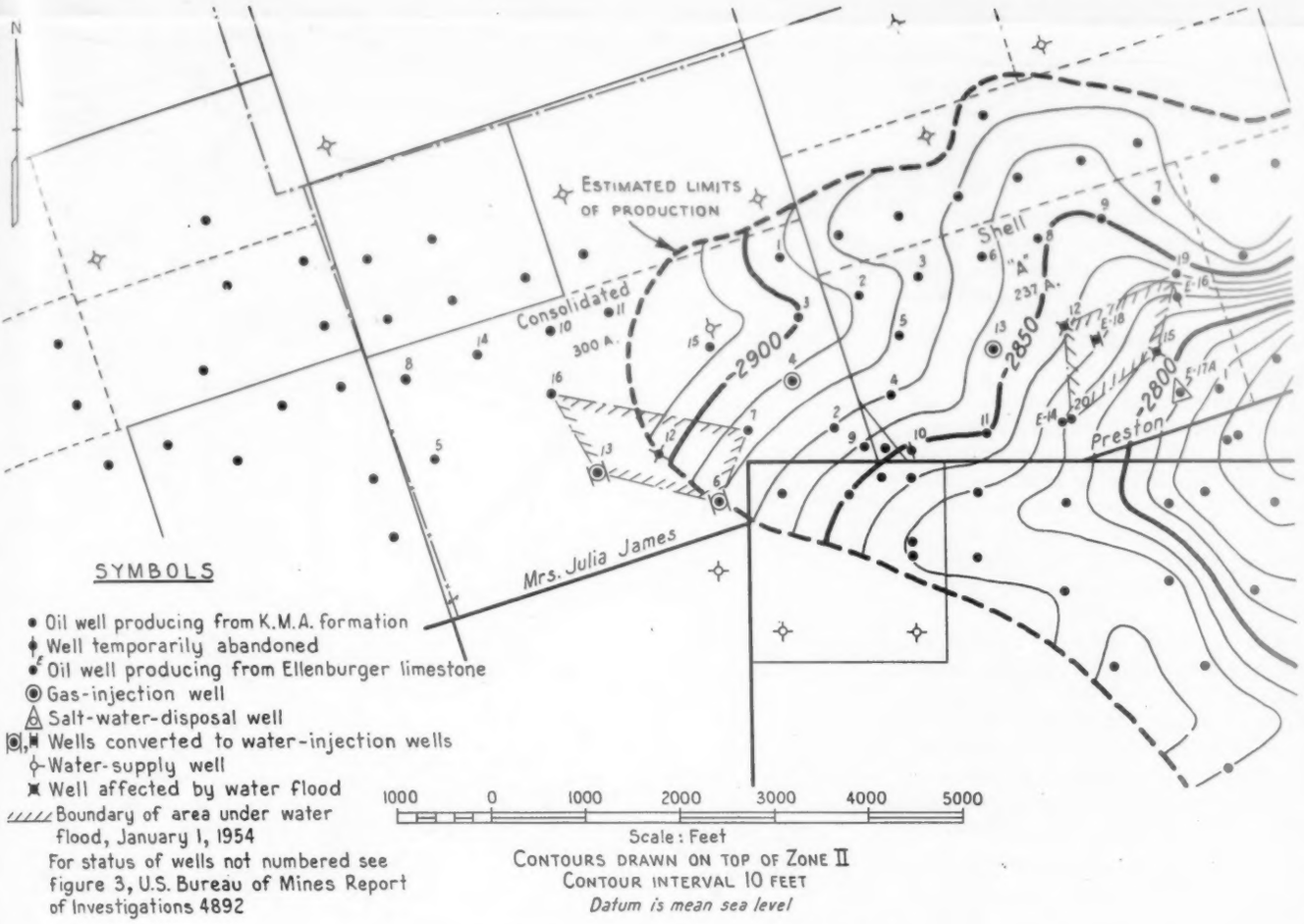

FIG. 23. Structure map of Zone II, part of Unit 6

Development of Waterflood

Water injection into Zone I was begun when gas-input wells No. 6 and 13 were converted to water-input wells in July, 1952.

The flood-pattern area, as outlined in Fig. 22 and 23 includes producing wells No. 7, 12, and 16. The area of the flood pattern is 29.4 acres. Zone I has a gross reservoir volume of 1355 acre-ft and averages 46.1 ft in gross thickness.

At the start of the flood, water was injected at a rate of approximately 220 bbl per day into each of the two injection wells at a wellhead pressure of 60 to 130 psi. During December, 1953, the injection rate was approximately 320 bbl per day in each of the two injection wells at a wellhead pressure of 50 to 100 psi. The pressure required to inject the water is supplied by the casing pump in the water-supply well. The input wells do not have tubing in the hole. To January 1, 1954, an overall average of 8.7 bbl water per day per injection well per ft of gross sand thickness had been injected.

TABLE 4. Analyses of core sections from zone 1, KMA formation, KMA field, Wichita and Archer counties, Texas, Gulf Oil Corp., Ferguson-Buffalo well No. 23 and Gulf Oil Corp., Ferguson-Howell well No. 33.

Well No.	Core from which section was taken, number	Interval from which core was taken, ft. below derrick floor		Average horizontal permeability, millidarcys	Ratio min. to max. horizontal permeability, per cent	Angle between max. and min. horizontal permeability axes	
		From	To			Degrees	Quadrants
23	2	3700	3701	36.46	86.6	90	—
23	4	3703	3704	25.05	31.4	60	2d & 4th
23	5	3704	3705	.116	15.9	30	2d & 4th
23	20	3712	3713	.062	71.1	90	—
23	6	3714	3715	23.94	90.2	90	—
23	7	3725	3726	.177	57.6	90	—
23	8	3726	3727	13.46	81.2	90	—
23	9	3728	3729	10.59	49.2	60	1st & 3d
23	10	3730	3731	13.10	69.1	90	—
23	11	3731	3732	.292	75.7	90	—
23	12	3736	3737	13.51	86.6	60	1st & 3d
23	13	3737	3738	7.59	79.3	30	2d & 4th
23	15	3741	3742	42.56	82.3	90	—
23	16	3742	3743	.473	80.3	60	1st & 3d
Summary, 14 core sections		3700	3743	13.31	71.7	85.7	2d & 4th
33	1	3706	3707	0.251	53.4	60	2d & 4th
33	2	3707	3708	.183	81.2	90	—
33	3	3708	3709	54.82	87.5	30	2d & 4th
33	6	3730	3731	33.09	71.5	90	—
33	7	3731	3732	76.97	77.3	60	1st & 3rd
33	8	3732	3733	.130	75.0	90	—
33	9	3733	3734	23.04	80.0	60	1st & 3d
33	11	3735	3736	44.11	76.4	90	—
33	12	3736	3737	.168	42.7	60	1st & 3d
33	13	3737	3738	75.24	85.1	30	1st & 3d
Summary, 10 core sections		3706	3738	30.80	80.2	84	1st & 3d
Summary, 24 core sections		3700	3743	20.60	76.9	90	
Summary, 15 core sections				Greater than 1 millidarcy	77.0	88	1st & 3d
Summary, 9 core sections				Less than 1 millidarcy	61.9	86.7	2d & 4th

Method of Completing and Operating Wells

No input wells were recompleted when they were converted for water injection. Casing is set 16 ft above the top of Zone I in well No. 6 and at the top of Zone I in well No. 13. Five feet of shale below. Zone I is open to the

well bore in well No. 6. The tubing was removed from the gas-input wells when they were converted to water-injection wells.

No remedial work was done on the producing wells when water injection was begun. They are pumped by standard surface jacks powered by gas engines and standard subsurface plunger-type pumps. The injection wells are equipped with a pressure gauge at the wellhead, a value to shut off the injection water, and a backflow drain line.

Source of Treatment of Injection Water

The brine used for injection is obtained from a water-supply well producing from a Cisco series sandstone. The well was drilled to a total depth of 1128 ft and equipped with 7-in. casing set at 1090 ft. The supply well is pumped with a 3¾-in. by 12-ft Lantex casing pump set close to the bottom of the hole.

The injection water is not treated and is pumped directly from the water-supply well through 2-in. tubing to the meter manifold and then to the input wells. The injection rate is regulated by chokes at the meter manifold.

An analysis of the chemical constituents of the injection water follows:

Radical	Ppm
Sodium (Na)	54,892
Calcium (Ca)	14,556
Magnesium (Mg)	381
Soluble silica (SiO_2)	12.0
Hydrogen sulfide (H_2S)	0.75
Free carbon dioxide	80.0
Turbidity	120
Supersaturation in bicarbonates as calcium carbonate	0
Chloride (Cl)	111,000
Sulfate (SO_4)	864
Bicarbonate (HCO_3)	49
Barium (Ba)	0
Dissolved iron (Fe)	15.0
Total iron (Fe)	17.5
Dissolved solids	181,762
Total solids	181,882

Indicated pH, 5.9
Specific gravity, 1.12 at 24° C.

Results of Waterflooding

A total of 315,171 bbl of water had been injected to January 1, 1954, without an increase in oil production. A small increase in oil production from well No. 12 was noted during the early part of January, 1954, which may indicate that the injected water is beginning to move the reservoir oil. If the pilot flood responds successfully, the operator plans to develop the lease with a line-drive type of pattern, using input wells along the southwestern edge of the lease and flooding updip.

Pertinent data of the project before and during waterflooding are given in Table 1.

Results of Directional Permeability Tests

The production statistics for individual wells in some KMA waterflooding projects indicate that the movement of injected water from input wells to producing wells is more linear than radial. The directional permeability of the reservoir rock could be one of several factors that would cause linear flow of fluids in the KMA reservoir.

To determine the possible existence and magnitude of directional permeability, a study was made of the horizontal permeability measurements of core plugs taken at 30 deg radial intervals around the circumference of the core and in the same horizontal plane. Cores from Zone I of the KMA formation from Gulf Oil Corporation Ferguson-Buffalo well No. 23 and the Gulf Oil Corporation Ferguson-Howell No. 33 were used for the permeability tests. Air-permeability measurements were recorded on core samples taken at 24 different levels along the two cores. The results of these tests are summarized in Table 4.

The directional permeability data indicate that a definite trend of maximum horizontal permeability exists across core section and that the trend generally is at right angles to the trend of minimum horizontal permeability. The permeability measurements at the 24 different levels in the two cores reveal that the maximum permeability exceeds the minimum permeability at an approximate ratio of 4:3 in a horizontal plane.

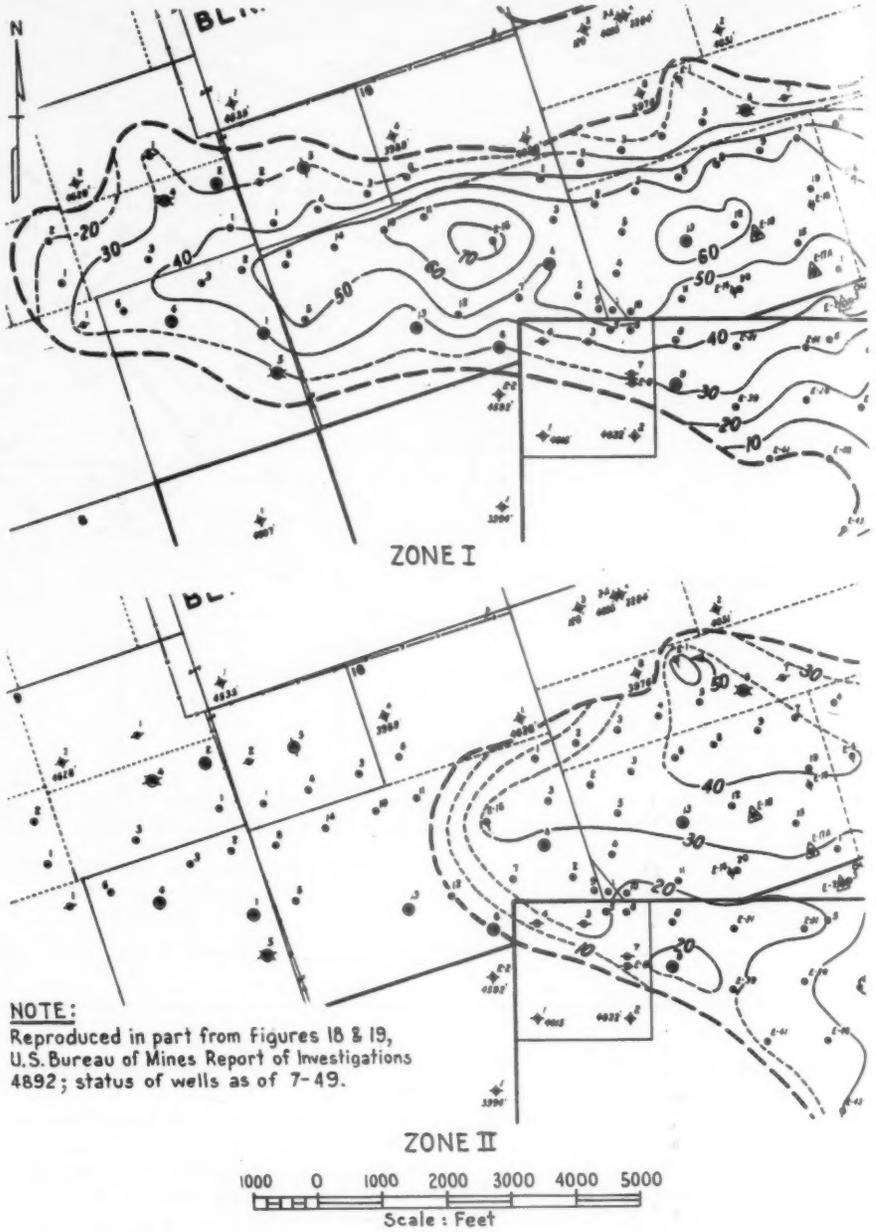
N
ZONE I
ZONE II
NOTE:
Reproduced in part from figures 18 & 19, U.S. Bureau of Mines Report of Investigations 4892; status of wells as of 7-49.
1000 0 1000 2000 3000 4000 5000
Scale : Feet

FIG. 24. Isopachous map showing gross thickness of Zones I and II in part of Unit 6

OIL FROM DIAMONDS?

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This ratio between maximum and minimum permeability is not as high as might be expected from observing the movement of fluids in the KMA reservoir. Further study on cores coupled with a detailed study of the movement of fluids within the reservoir is warranted. If directional permeability is a predominant influence in the movement of fluid in the KMA reservoir, the injection wells should be spaced to provide the most efficient flood pattern.

Conclusion

Although waterflooding in the KMA field is still in its infancy, the active and abandoned waterfloods, both succesful and unsuccessful,, have definitely proved that oil can be moved through the reservoir by the injection of water.

A study of waterfloods in this report indicates that the operators who are flooding Zone II in the southwestern part of the field have encountered production problems that must be overcome before this zone can be economically flooded. High produced water-oil ratios early in the life of the floods, caused by injection water bypassing either through streaks of very high permeability (1500 to 2500 md) or through oil-barren sections of rock open to the well bore in the injection wells, must be reduced before Zone II can be flooded successfully. This area should not be condemned until one or more comprehensive pattern-type pilot floods have been tried.

All waterfloods in Zone I have not shown a favorable response. It is believed, however, that the results obtained by waterflooding this zone can be improved if the operators will complete their injection wells so that the injected water will be confined to Zone I, consider the structural features of the formation when designing the flood pattern, and balance the injected water either volumetrically or by pressures.[2]

The fact that the two pilot floods in Unit 3 are being expanded into one, which will cover over 3000 acres, is good evidence that the operators believe the KMA reservoir in the area can be successfully waterflooded.

Prolonged operation of floods in a pilot stage, regardless of the results obtained, may have harmful effects on the volume of oil that can be recovered by an expanded program. If the results obtained within a reasonable time are not favorable, either the trouble should be ascertained and remedied or the injection of water temporarily discontinued until a decision can be reached regarding the future status of the project. If the results obtained are favorable, the flood should be expanded into full-scale operation or the injection of water should be discontinued until the expanded program can be placed in operation.

Acknowledgments

This report was prepared at the request of the North Texas Section of the AIME and the Production Committee of the North Texas Oil and Gas Association.

The part of the report prepared by the Bureau of Mines was done under a cooperative agreement with the North Texas Oil and Gas Association.

The writers sincerely appreciate the fine cooperation of the executives, engineers, and the field personnel of all of the oil companies and operators waterflooding in the KMA field in generously supplying the data, information, and assistance requested for this report.

The writers also acknowledge the assistance of the following members of the Bureau of Mines: K. F. Anderson, C. J. Wilhelm, E. L. Comer, J. M. Seward, W. C. Elliott, Jr., Paul Meadows, and M. E. Hawkins.

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Donnell Drilling Company's Rig No. 10, which drilled a recent Spraberry well for the Hanley Company in 14 days, 16 hours.

P 425.26

Contractor-Operator Teamwork . . .

Cuts Spraberry Drilling Time

Donnell Drilling Company of Odessa, Texas, Finishes Well in 14 days, 16 Hours.

MANY people think of the Spraberry Trend as a "dead" area as far as drilling activity is concerned. And, it is far different now than it was in the spring of 1952, when more than 200 rigs were at work in the area. More than 20 rigs, however, have been at work in the trend throughout the last two years, and activity continues lively. Many drilling contractors have steered clear of work in the Spraberry since the footage price now is approximately ⅔ of the standard $6.00 per foot, which prevailed during "the boom."

That a drilling contractor can operate profitably now in the Spraberry is illustrated by the performance of Donnell Drilling Company's Rig No. 10, working on the Aldwell Lease for the Hanley Company. This rig has just completed its fifth well for the Hanley Company, the Aldwell A-2, in 14 days, 16 hours. This is no "one-shot" record-breaking attempt; the previous well, the Aldwell B-1, was drilled in 14 days, 18½ hours. None of the five wells have taken more than 18 days.

When this drilling performance is compared with the usual 25 to 35 days required to drill a lower Spraberry well during the boom, there is "something extra" that has been responsible. That "something extra" is the cooperation and understanding of the Hanley Company personnel, planning and working with the Donnell men. This teamwork was apparent from the time the rig moved onto the lease for its first well.

The operator furnished a water well and line pipe for the water line. The contractor's crews laid the water line. The water well was drilled in a central location on the lease, and a lease tank battery was erected nearby. After each well is completed, the water line is left in place and becomes the flow line for the producing well.

Everything possible is done to reduce the time on location for the drilling rig. Before the rig is skidded onto a new location, the surface hole has been drilled and 350-ft of 9⅝-in. spiral-weld casing has been set by a cable tool rig. Cement has been circulated on this surface pipe. A rathole and mouse hole have been dug by a small "shot hole" rig, and the mud pits have been dug and filled with water. An extra 500 bbl tank on the new location also is filled with water. The rig is skidded on location with the kelly in the derrick and the rathole and mousehole casing standing in the derrick. Once the rig is spotted and pump is skidded in and belted, drilling operations can proceed at once.

Drilling Rig. Donnell's Rig No. 10 is powered by two 360-hp gas engines. The mud pump is a 450-hp, 8 by 16-in. unit and is driven off the drawworks power compound. A double gate blow out preventer with hydraulic controls is used. A 131-ft, 625,000-lb jackknife derrick completes the major surface equipment list. Four inch OD drill pipe with 4-in. hardened tool joints is used above twenty 6-in. OD drill collars with 2¼-in. bore.

In drilling the 7⅞-in. hole from 350 ft to 7700 ft., thirty rock bits were used. The first six of these, to 4280 ft, were jet bits. Nine hundred psi pump pressure was used with the jet bits.

Mud Program. Drilling out from under the surface pipe, clear water was used as the drilling fluid to a depth of 4000 or 4500 ft. Circulation was through the reserve pit while drilling with clear water; when starting to mud up, circulation was through the mud pits. As the mud was mixed, crude oil

was added through a ¼-in. choke nipple in the mud pump suction. No emulsifying agent was used, and crude oil was added continuously as drilling progressed. A total of 995 bbl of oil was used on the Aldwell B-1.

The mud was made up on a salt-gel base with fibertex, and cotton seed hulls added. Viscosity was maintained at 34 increasing to 40 as required. Mud weight was 9.7 lb per gallon when first mixed and was reduced to 9.1 lb per gallon as the producing zone was approached. Hanley made no requirement on the drilling contractor regarding mud quality, viscosity, or water loss.

Cementing Practice. The Hanley Company's cooperation to reduce lost rig time is further illustrated when the 5½-in. casing was run. The casing string was made up of 7700 ft of 5½-in. casing (66 joints of J-55 15.50 lb, 115 joints J-55 14.00 lb, 63 joints of J-55 15.50 lb.) In cementing, the following materials were added in the order given: 10 sacks Posmix, 3 sacks Signalite, 3 sacks lime, 10 sacks Posmix, 3 sacks Signalite, 125 sacks cement 2 per cent gel, 250 gal mud acid on plug. Plug was pumped down with oil.

Once the casing string was run, pipe was set on the braden head and the cement head was set under the floor. While the cementing company was mixing cement and pumping the plug down, the drilling crew was tearing down preparing to skid. Actually, the rig was released once the pipe was set on the braden head, and the cementing head was in place. The rig was skidded on to the next location, where surface hole had been dug, pipe set and cemented, rathole and mousehole dug, pits and water tank in place and filled with water. Everything was set too start drilling again! On the move from the Aldwell B-1 to the Aldwell A-2 (about ½ mile skid move) only 10 hours were required to skid, rig up, and start drilling. The following schedule tells the story:

ALDWELL B-1

Drilled Plug—11:00 P.M.—5-21-55
Total Depth 7700 ft—5:30 P.M.—6-4-55.

13 Days	18½	hr drilling time
	6½	hr circulating, laying down pipe and drill collars
	7½	hr running casing, mixing cement, and pumping down plug
	10	hr skid and rig up and begin to drill plug
14 Days	18½	hr

Fast Time—Yes! And it can be done when producing company and contractor cooperate to minimize problems. ★ ★ ★

PERSONNEL ON A DRILLING RIG

Gene Graham*

THE personnel on an oil well drilling rig consists of a group of operators who have certain skills and functions which are uniform in the business of drilling a well, and they will be described below. These operators are artisans of a sort who ply their trade as do carpenters, bricklayers, etc., not caring so much for whom they work as they do for the opportunity to work on a rig.

A drilling rig operates 7 days a week, 24 hours a day, and a full staff must be on the job at all times in order that the rhythmical teamwork-type of operation may be accomplished without delays. Drilling rigs are generally staffed, for a tour (pronounced "tower") or shift, by a crew of 4 or 5 men. Four man crews are used on the small shallow drilling rigs, and 5 man crews are used on the larger rigs.

Each 5 man drilling crew consists of a driller, a derrickman, a catheadman, and two floormen (rotary helpers).

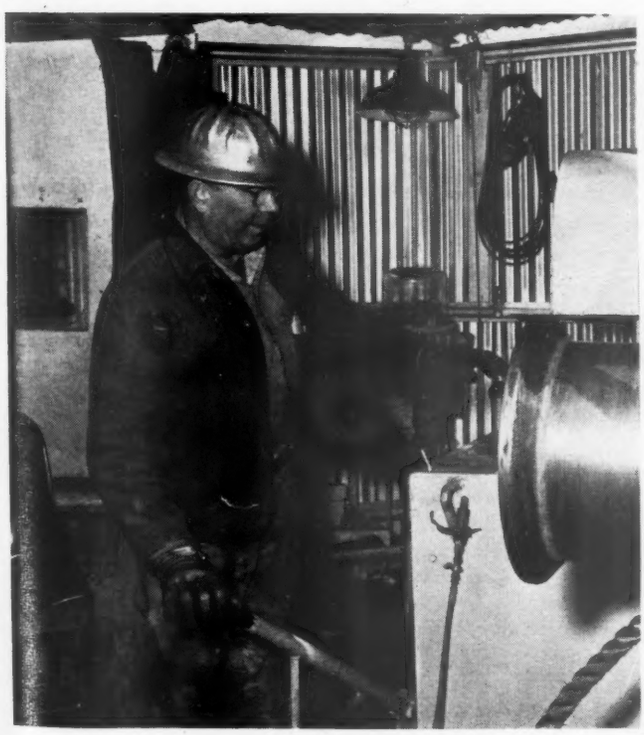
The Driller

The driller is in charge of his crew, and in charge of the rig's operations during his tour. He reports to a foreman who is usually called a "toolpusher."

In his position as boss of the rig and the crew, the driller must be responsible for safe, economical operations at all times. He always has a background of experience in performing the jobs of those men working under him; he knows thir problems and what is required of them by having done this work himself. The relationship between the driller and his crewmen is such that the driller will often take his crew with him when he changes jobs.

Good judgment and alert attention to detail are probably the two prime requisites of a driller. They are necessary to safeguard the lives of his fellow workers and to protect the huge investment of his employer.

*Executive Vice President, Thomas P. Pike Drilling Co., Los Angeles, California.



The driller operates the drawworks.

The derrickman tests the drilling fluid.

Specifically, it is the driller's function to operate the drawworks in the hoisting of the drilling string (drill-pipe and tools) from the hole and in running it back into the hole, as well as to maintain the proper characteristics of the machinery while drilling with a bit on bottom. The weight on the bit, the speed of the rotary table, the pressure and volume of the mud circulating fluid and are some of these characteristics.

The Derrickman

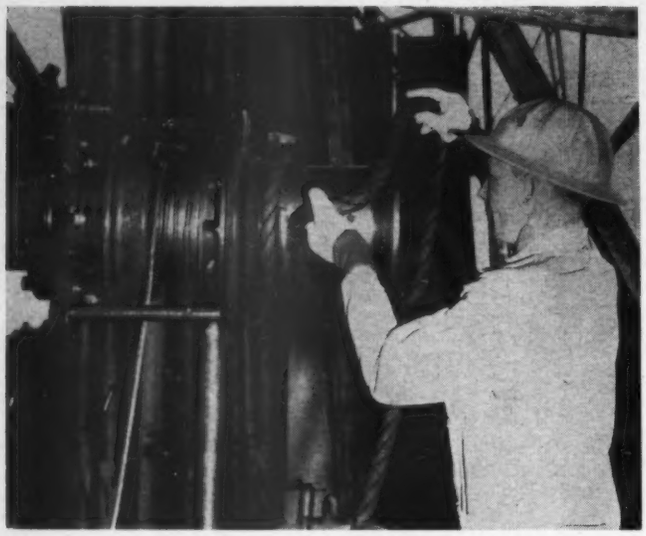
The derrickman works high in the derrick or mast while "making a trip," that is, when the pipe is being hoisted from the hole or run back on bottom. Stationed on the derrick platform known as the "monkey board," which is 90 ft above the derrick floor, it is his function among others to seize the upper end of the 90-ft stand of pipe as it comes out of the hole and pull it over into the rack.

He also tests the circulating fluid to maintain its properties in accordance with the mud program specified for the well. It is his responsibility to assure the proper functioning of the mud pumps; to check their operation frequently; to replace worn parts, and to provide the pump's efficient operation at all times.

The Catheadman

The term catheadman is applied to the third ranking member of the drilling crew. Some contractors term this man a motorman. He is usually more experienced in all phases of the work than the rotary helpers.

His job is to operate the manual catheads on the draw-



The catheadman is sometimes called motorman.

Rotary helpers operate the tongs.

works whenever they are used and to supervise service of the motors and engines for uninterrupted operation. It is he who adds oil when needed, supervises the oil changes, watches the radiator water and generally performs the function of a serviceman with respect to the motors.

Rotary Helpers

The two rotary helpers are the tong operators during a trip. It is their job to see that the tongs are placed properly on the drilling string, to rack the pipe and to be ready for the next similar operations in rhythm with the machinery as operated by the driller. When the bit is on bottom drilling there are 101 miscellaneous duties for the rotary helper to perform.

Maintaining the rig's housekeeping is a large order in itself—straightening up the floor; picking up numerous pieces of equipment; cleaning and painting the machinery; helping the motorman with the engines; helping the derrickman with the mud treatment, etc.

It was stated earlier that the large rigs have 5 man crews and the smaller rigs 4 man crews. The usual difference is that there is one less rotary helper or floorman on a 4 man crew rig.

The Foreman or Toolpusher

The toolpusher is actually the manager of his branch of his company's operation. During the drilling of the well he must be available at any time day or night for consultation with the drillers. He is the Management of the drilling company insofar as his crews are concerned. In today's fast moving contract drilling economy, the toolpusher must have at least a smattering of knowledge on labor laws, personnel relationships, of chemistry (for mud control), hydraulics (for circulating fluid), internal combustion engines, etc., etc. He is the key man in any drilling contractor's organization. He usually has authority to spend money to keep his rig in operation, cooperating, of course, with his spervisor on any items of major importance. Since he does not drill a foot of hole himself, it could be said that his prime function is to assist the drillers and their crews to drill the hole safely, economically and promptly.

The foreman makes his headquarters in an office at the rig known as the "doghouse," where he must keep accurate records of daily drilling, performance, purchases of materials, accident reports, and other paperwork which must go daily to the main office for coordinating with the other company accounting and records. Here he also interviews salesmen from the supply houses, consults with the production superintendent and other personnel from the producing company and is available by telephone to the outside world which may be many miles away. When he leaves the rig, he usualy is still in touch by mobile telephone.

The foreman's responsibilities cover every operation of the rig including clearing and staking out the drillsite, moving in the rig, and rigging up and tearing it down when the job is finished.

Drilling Superintendent and Assistant

Depending upon the size of a contracting organization, there may be an assistant drilling superintendent as well as a drilling superintendent. Again, it is the function of these men primarily to aid the toolpusher in the conduct of their work. The drilling superintendent usually has authority to authorize the expenditure of larger sums of money than do the toolpushers. Usually there is a limit placed by top management on the amounts that any foreman of whatever rank may spend without top management's approval.

* * * * *

These are the duties of the principal field personnel on a drilling rig. Behind them in the administrative end of the business, an office force must be maintained to solicit business, contact clients, estimate for bids, maintain an equipment yard and repair shop and figure what the company has left after taxes.

This type of personnel is much the same as in any other type of contracting business. In oil well drilling, the walls of the general manager's office are covered with maps showing the locatoin of each company rig, and with charts and graphs which show the daily drilling progress on each job, with the normal curve of the estimate beside it for constant comparison.

A fishing job, a bad accident, or even an unexpected zone of tough going may cause the performance curve to fall away sharply from that laid out in the estimate, but that's the nature of the business. A drilling contractor has to be prepared to weather runs of hard going as part of normal business expectations. To weather these low spots successfully, he needs the kind of field men and teamwork which can make up for losses by drilling more hole at less cost when the going is according to estimate.

INSTRUMENTS

Karl L. Kellogg*

FOR the purpose of this chapter, only those drilling instruments used in the actual drilling operation will be discussed. Instruments applied to testing and well completion are covered in other chapters. As a general classification the drilling control instruments are those that give a continuous indication of the variables under the control of the driller, and whose proper interpretation can give the greatest degree of control over the rate of penetration, hole deflection and bit life.

The art of oil well drilling is fast becoming, like other purely mechanical operations, a science of reading, correlating and interpreting the information available through the use of sensitive, relatively fool-proof instruments. "Drilling by the seat of one's pants," once an expression about as commonly used as "flying by the seat of one's pants," is now about as obsolete in the art of rotary drilling as the latter is in the flying profession. Much technological advancement has been made in the instrumentation of oil well drilling and considerably more is anticipated or is in the development stages.

The main control instruments are the weight indicator, mud pressure and volume instruments, rotary torque gage and tachometer. The *application* of these instruments and the *interpretation* of the data obtained therefrom is an art that must be learned and effectively applied by the driller if maximum efficiency is to be obtained in rotary drilling.

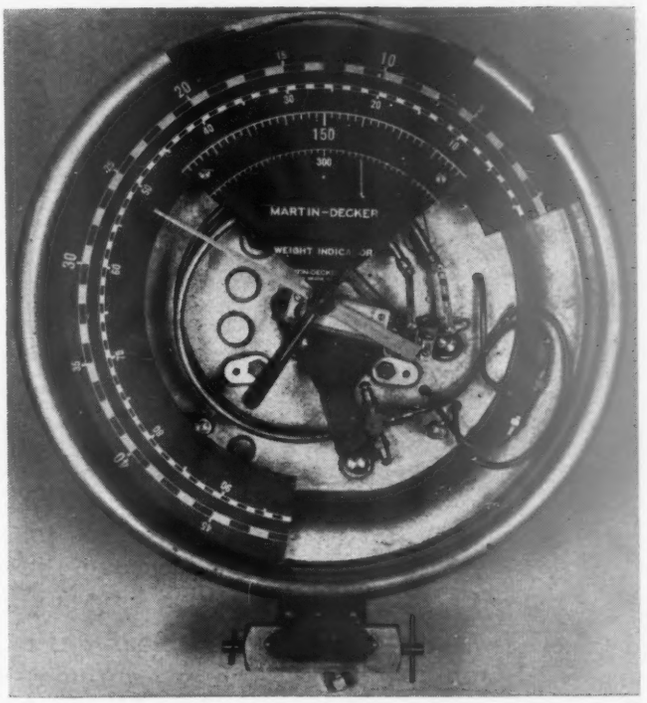


FIG. 1. Cutaway of a typical gage. The pressure transformer develops the hydraulic pressure per square inch throughout the whole system. It is transmitted uniformly through the copper tubing at right and into the C-shaped Bourdon tubes, effecting a straightening action and causing the linkage on the tube tips to pull the quadrant levers. These, in turn, rotate the gears to which pointers are attached.

Weight Indicator

The weight indicator is the primary drilling control instrument. It is used to control the weight that is applied to

*President & General Manager, K. L. Kellogg & Sons, Compton, Calif.

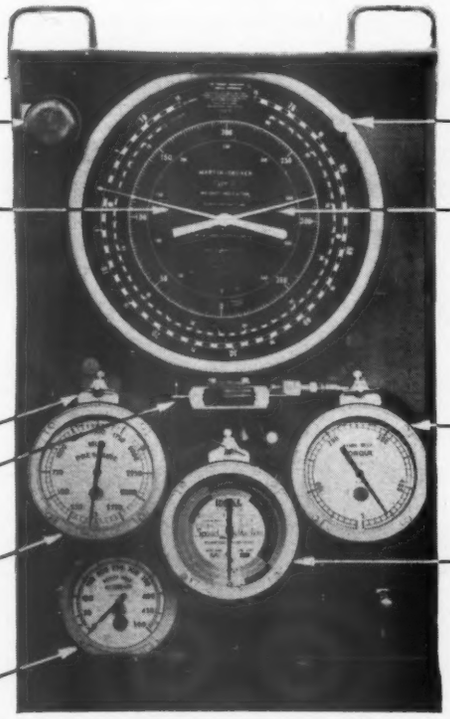

Vapor-proof light for safe illumination around combustibles.
Red hand shows the net-weight-on-bit on outer dial, and serves as a vernier on inner dial for fishing, milling, cutting, etc.
All hydraulic gauges have manually operated dampers for controlling pointer fluctuations.
Mud-pump-pressure gauge at driller's position immediately warns of pressure changes.
Tachometer shows actual RPM of rotary table.
Knurled knob for setting outer dial on zero with bit off bottom. Net weight placed on bit is then read directly.
Yellow hand indicates hook load at all times (on inner dial)—showing tight hole, stuck pipe, etc.
Torque gauge indicates bit conditions, and warns of dangerous excess torque.
Drawworks speed selector shows driller what gears to use for optimum hoisting speeds without overloading.

FIG. 2. These instruments, grouped for driller's convenience and to expedite moving, take the guesswork out of modern drilling.

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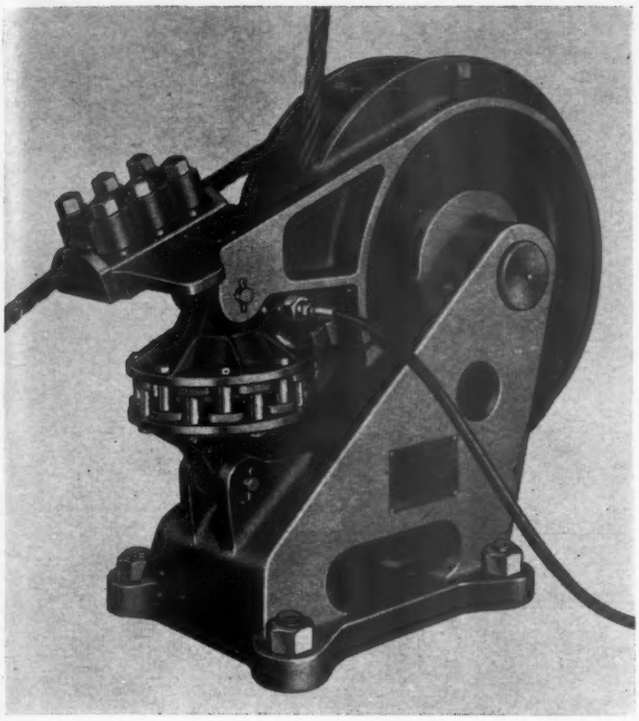


FIG. 3. Besides providing the mooring for the deadline, this type of anchor houses the pressure transformer that transmits hydraulic signals to the weight indicator.

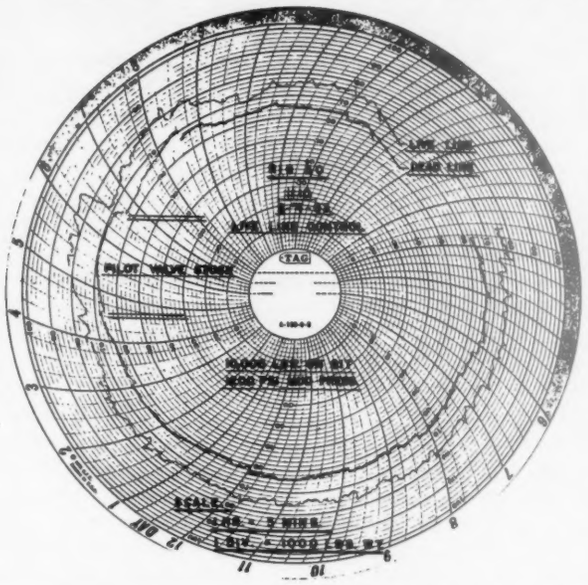


FIG. 4. Simultaneous recording of dead line and live line weight indicators.

the bit while drilling as well as indicating the total weight applied when running-in, hoisting, fishing and such weight measurements necessary to the operation of certain types of testing and specialty tools. The weight indicator is therefore a safety device as well as an instrument providing for greater efficiency in the actual drilling operation.

The importance of controlled weight while drilling cannot be minimized, for without this control drilling rates would be greatly impeded due to reduced bit lift, as well as hole deflection and twist-offs resulting from overloading and fatigue of drill pipe and tool joints. Likewise to be considered is the element of safety to equipment and men. Overloading while fishing and/or while pulling on stuck drill pipe might result in serious economic losses and jeopardy to the welfare of the crews working on the rig floor.

Hole drift and drill pipe fatigue resulting from buckling of the drill pipe within the circumferential extremities of the hole, and caving of the hole which may result from such buckling, are conditions which may be controlled by careful application of weight somewhat under established critical limits. On the other hand, directional drilling often requires intentional overloading to maintain the desired angle of deflection. Successful fishing jobs often require extremely accurate bit weight and hook load indications. Automatic feed control systems operate on a constant weight principle, taking their signal from a surface weight sensing element.

There are several different types of drilling weight indicators available to the operator. The simplest type is a mechanical unit with an integral gage that clamps on the dead line and gives a continuous indication of hook loads. Historically, this is the kind that was first universally accepted by the drilling industry. But because of the severe dead line whip that the instrument was subjected to, plus the fact that the instrument was often so far away from the driller that reading was difficult, unitized weight indicators gave way to remote indicating ones. Today, for the most

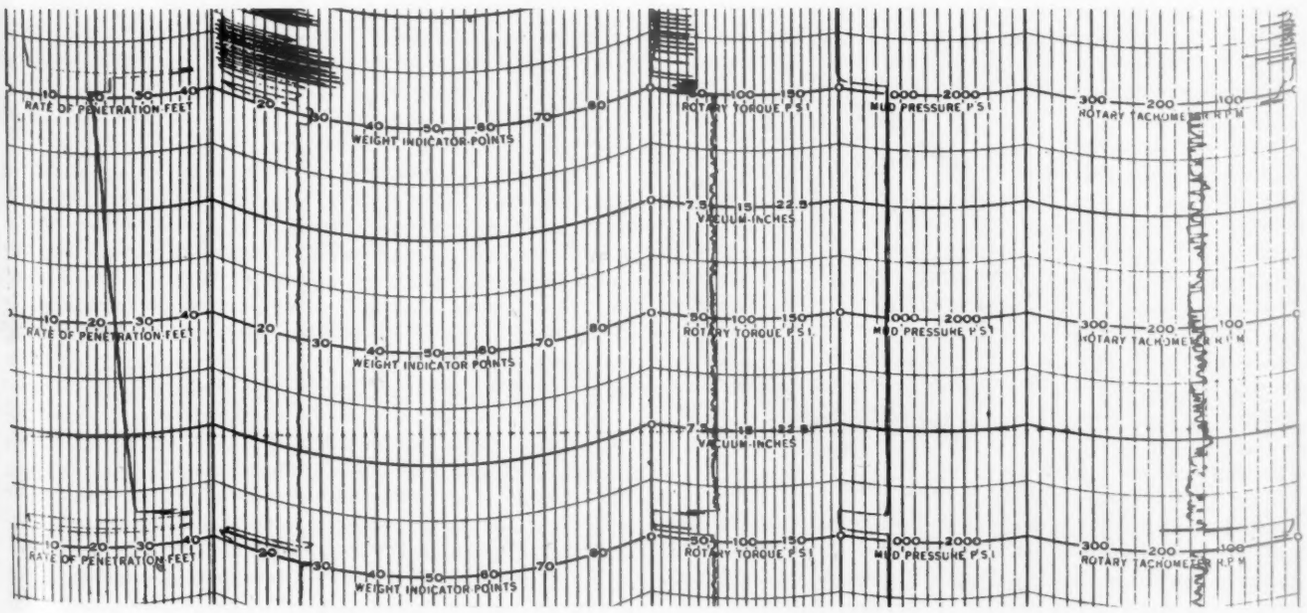


FIG. 5. Typical recording of principal factors affecting rate of penetration.

part, unitized weight indicators are used as emergency, testing or standby instruments.

Another type of weight indicator has a deflection-type diaphragm on the dead line, connected by high-pressure hydraulic hose (at one time copper tubing was used) to the indicator at the driller's position. This type of instrument, a great improvement in its day, is seen today mostly on service rigs or at locations where fairly shallow holes are being drilled. It has the advantages of low cost, portability and simple installation.

Later types of weight indicators provide dials for direct reading of weight on bottom in addition to hook loads, compound pointers for amplified readings of small weight variances, and can be equipped to provide graphic recordings. The most modern unit of this type takes a signal from a stroking diaphragm pressure transformer installed in a wire line anchor fastened to the dead line. Weight changes are transmitted hydraulically to the gage located at the driller's position. The wire line anchor consists of a snubbing drum and lever arm. Drum is free to rotate, except as restrained by pressure transformer. Dead line load is thereby converted to a pressure signal to actuate the weight indicator.

Rate of Rotation Instruments

Generally speaking, rate of penetration while drilling is directly related to weight on the bit and rate of rotation. High penetration rates and short bit life will usually result from heavy weight and high rate of rotation, while low penetration rates and long bit life will result from light weights and low speeds. Somewhere in between is an optimum relationship between these variables for every given condition.

Since rate of rotation is an extremely important factor in this calculation it should not be given to guesswork on the part of the driller. Simple tachometers are available for all rotary tables and rig designs. Many types are available to suit all rig designs. A cable driven assembly is simple and dependable for short distances from takeoff to head. An electric type is the best solution for transmission through lengths greater than 15 or 20 ft. These may be either generator transmitter or separately energized selsyns.

The penumatic rotary table tachometer provides for both indicating and recording the speed of rotation since it is operated by air pressure which is also available to actuate a recorder pen.

Rotary Mud System Instruments

The rotary mud system performs a number of important functions and its careful control and efficient operation is vital to obtaining effective results in rotary drilling. Besides its functions of maintaining the hole, holding back formation pressures, cooling the bit and removing cuttings, it supplies an additional force for cutting the hole.

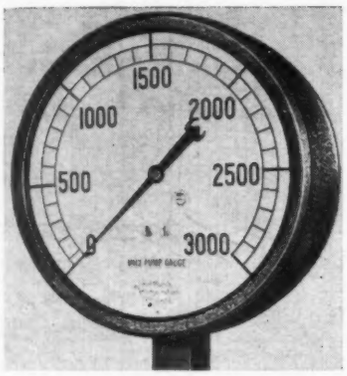


FIG. 6. Mud pump gage.

The mud pump pressure gage is the primary mud system instrument. The gage generally consists of a dial which is connected to a self-containing diaphragm unit which is placed in the discharge line of the pump. The gage can be located at the pump or in the drilling instrument cabinet at the driller's position. At any rate, the dial should be calibrated in large, legible figures and gage should be sensitive to small pressure changes, and damped to stabilize the pointer at the mean pressure level.

Since obtaining maximum mud volume is the most important factor in supplying force for cutting the hole, a pump speed and volume indicator can be used in conjunction with the pressure gage to aid the driller in maintaining the pump's operation at maximum performance.

For most effective operation the pumps should be operated, without overloading, at maximum speed using maximum size liners. Any change in mud pressure should be immediately detected. A pressure rise will generally indicate a plugged bit. A pressure drop may be caused by a loss of pump speed, a cut pump valve, worn piston, scored liner, washout, lost circulation or other conditions.

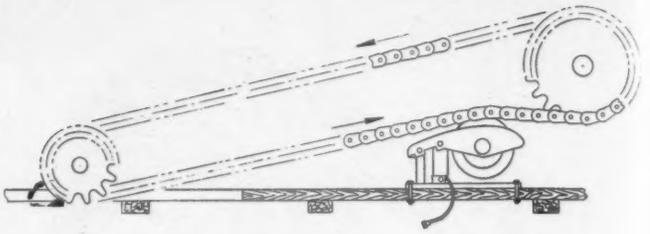


FIG. 7. Chain actuated torque gaging unit.

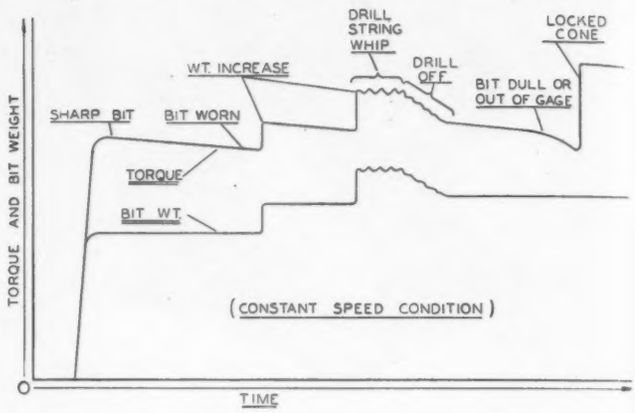


FIG. 8. Generalized torque gage interpretation.

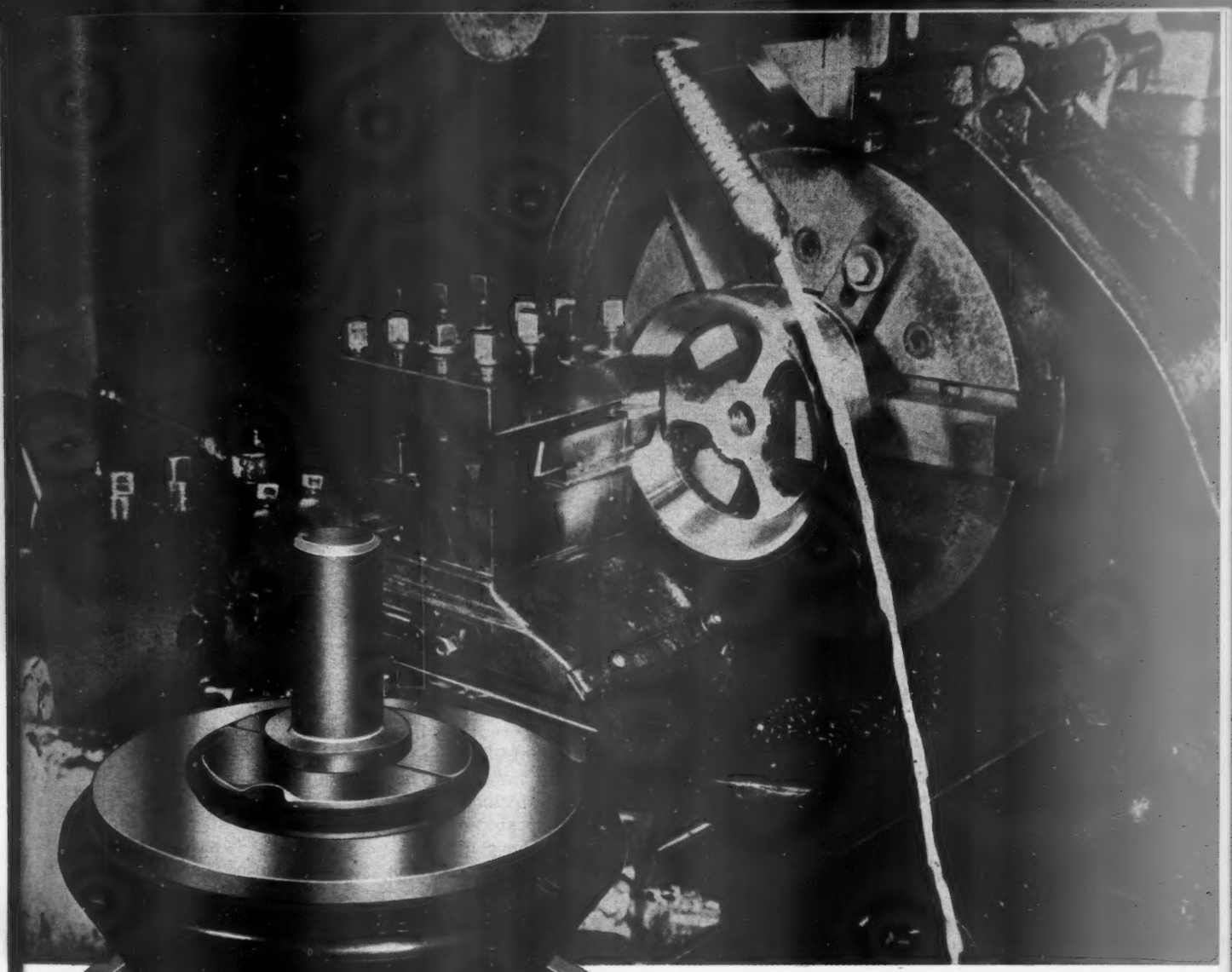
Torque Gages

The most valuable service of the torque gage is to minimize the danger of twist-offs. However, improvements in torque instruments during recent years now afford the operator other valuable information in coring, reaming, milling, washing over, directional and deep hole drilling, as well as bit condition determination. The most modern type torque gages, because the gage differentiates between the work required to overcome hole friction and that which is being done by the cutting tool, enable the driller to determine exactly what his cutting tool is doing regardless of hole friction and rotational speed.

An especially designed instrument for adaptation to chain driven rotaries consists of an idler sprocket mounted underneath and deflecting the tight side of the rotary chain. A load sensitive element is also connected to the lever arm to which the idler sprocket is attached. With any build-up of torque, increased tension is placed on the chain, forcing it down which in turn depresses the idler sprocket, increasing hydraulic pressure in the load-sensitive element which is transmitted to a dial at the driller's position.

A similar device is adaptable to shaft driven rotaries consisting of a special spider with flexible spokes which drives the rotary clutch. The spokes deflect under load, controlling the output of a pneumatic gaging element. The latter method is not readily adapted to field installation but may be installed as original factory equipment.

The gage is designed with a rotatable dial, permitting the driller to "zero out" friction on drill pipe while rotating off bottom. Net work being done by the bit can then be meas-



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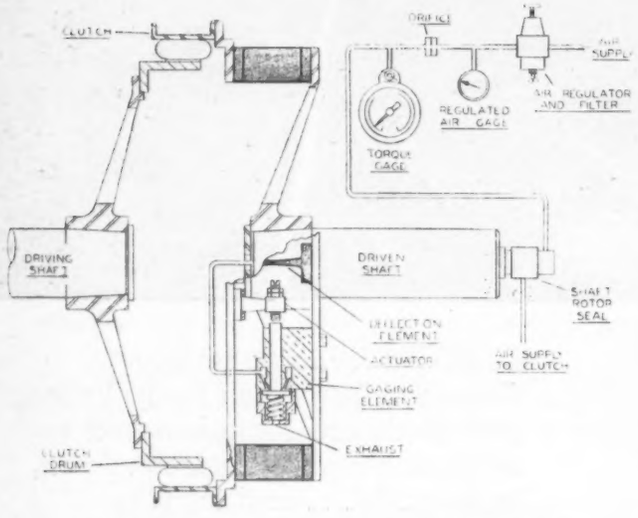


FIG. 9. "Ideal" torque meter schematic assembly.

FIG. 10. A tong-torque gage guarantees uniform tonging and prevents the two basic causes of drill-collar failure: Overtonging, which causes galled threads; and running collars too loose, which allows the joints to work, resulting in cracks and washouts. The gage has two pointers, one which can be set manually as target for the other.

ured and bit condition from green to dull, locked cutters or out-of-gage wear can be detected.

Vacuum torque gages are also in common use on internal combustion engines. They measure the vacuum on the engine, in turn indicating the torque on the drill string. The dial is located in the instrument cabinet and can be equipped for continuous recording. A vacuum torque gage is required for each engine so that additional gages are required for compounded rigs.

Auxiliary Instruments

These instruments do not primarily report information concerned with cutting the hole; but information related to maintaining the hole, performance of equipment and safety.

Rate-of-penetration measuring and recording devices are available in several types. One gives an intermittent count of time per increment of hole made. Others record rate of penetration of bit in feet vs. unit time. These records are useful to geologists and petroleum engineers for study and evaluation.

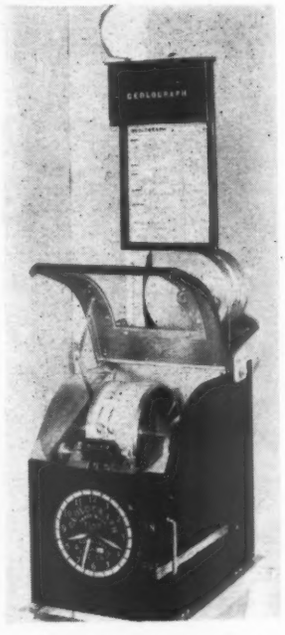


FIG. 11. Mechanical well logging device.

Continuous control of the drilling fluid can be approached by the use of certain indicating and warning devices. Gas cutting is detected at an early stage by means of an automatic mud weigher. An indication of circulation loss is given by a pit level signaling instrument.

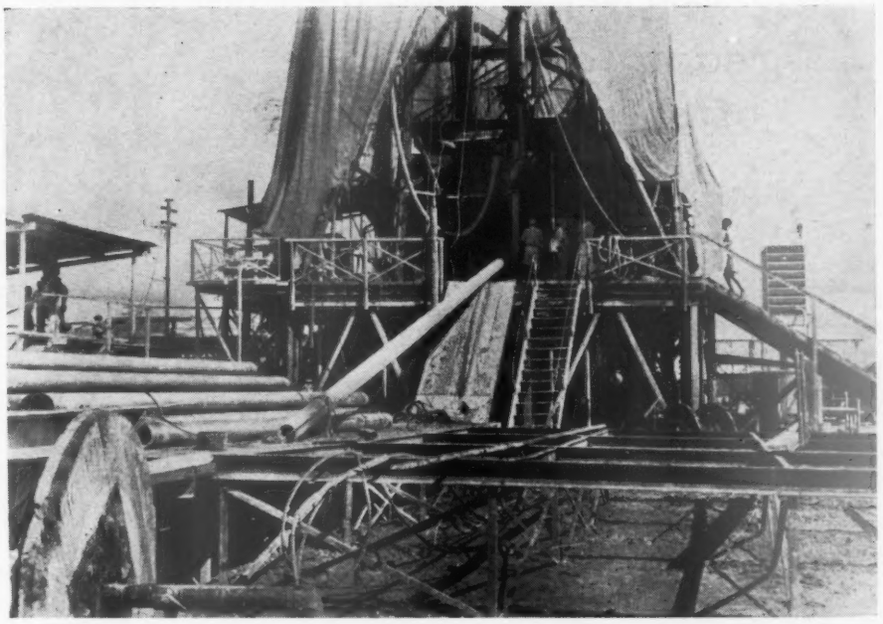
Make up of drill collar and tool joints can be uniformly controlled by use of a tong torque gage. Such instruments eliminate "feel" and guesswork in joint tonging. Proper make-up is especially critical on the drill collar joints and cross-over substitutes between collars and drill pipe. This instrument is adaptable to casing tongs and can be of value in maintaining uniform and proper joint make-up.

"Super" Size Drill Collars Used in Deep India Well

Drill collars measuring 40 and 50 it long and up to 12-in. in outside diameter were used by the Assam Oil Company, Ltd., in drilling to a total depth of 10,500 ft in the Nahorkatiya field of Upper Assam in India. The company is a subsidiary of Burmah-Shell.

Collars 12 in. OD and 50 ft long weigh 18,000 lb each. Assam also employs drill collars 10 in. in diameter by 50 ft long, as well as 10 in. OD by 40 ft. Hole and casing program to total depth was as follows: 29½-in. hole with 24½ in. casing to 100 ft; 20-in. hole with 16-inch casing to 1000 ft; 14¾-in. hole with 10¾-in. casing to 7000 ft; and 9½-in. hole with 7-in. casing to total depth.

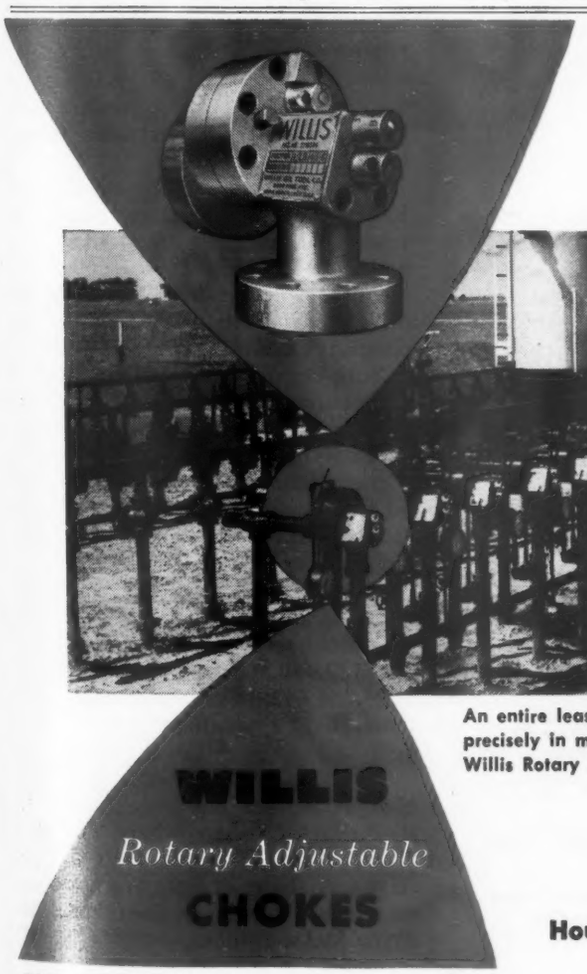
To drill a 14¾-in. hole to 7000 ft is a problem in nearly and oil field; it is particularly difficult in the Nahorkatiya field where formations are hard, entailing high rock bit expense, and marked by steep dips. The "super" size drill collars, made at Torrance, California, were used in order to obtain adequate weight on the bit for straight-hole drilling. Because of the additional drill collar length, fewer joints are necessary in the drill collar string.



—*Photo courtesy The National Supply Company*

"Super" size drill collars used by the Assam Oil Company, Ltd., in Upper Assam, India, are being laid down after drilling a 14¾-in. hole to 7000 ft. Total depth was 10,500 ft.

Last year's discovery in the Nahorkatiya field, near the starting point of the Burma Road, was the first in 60 years in territory that now comprises India. This field is about 20 miles southwest of the old Digboi field.



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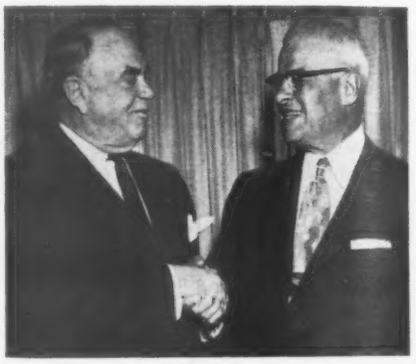
BJ, Borg-Warner Union May Boost Sonic Drill

"More rapid than expected" progress on the sonic well drill may be expected as a result of the proposed merger between the Byron Jackson Company, Vernon, California, and the Borg-Warner Corporation, Chicago, Illinois. Heads of the two companies indicated that the union would be accompanied by immediate and long range expansion in electronics, petroleum and other industries.

Approval of the merger by the board of directors of both companies recently, was followed by a BJ announcement, that it had purchased a 38½-acre tract in Sana Ana, California, for



E. S. Dulin, president of Byron Jackson Company, and Roy C. Ingersoll, president and chairman of the board of Borg-Warner, shake hands on the proposed merger of the two companies.

construction of a highly modern electronics plant and electronic testing laboratories.

Closely linked are the entrance of BJ, long-time manufacturer of oil field equipment, into the electronics field, and of Borg-Warner experimentation on the new sonic drill. Testing of the drill is now in its final stages at that company's North Hollywood plant.

Borg-Warner is a manufacturer of automotive, aircraft and agricultural implement parts and household appliances. Byron Jackson is well-known as a manufacturer of centrifugal pumps, oil field tools and services, and more recently, of electronic devices and nuclear power components.

Merger of the two firms, subject to approval of the stockholders August 26, would result in a working capital of $132,449,568 and total assets of $298,248,642. Combined sales volume should approximate a half-billion dollars.

A proxy statement containing the plan of merger has been mailed to Byron Jackson shareowners. The plan provides that BJ stockholders will receive four shares of Borg-Warner common stock for each five shares of Byron Jackson stock.

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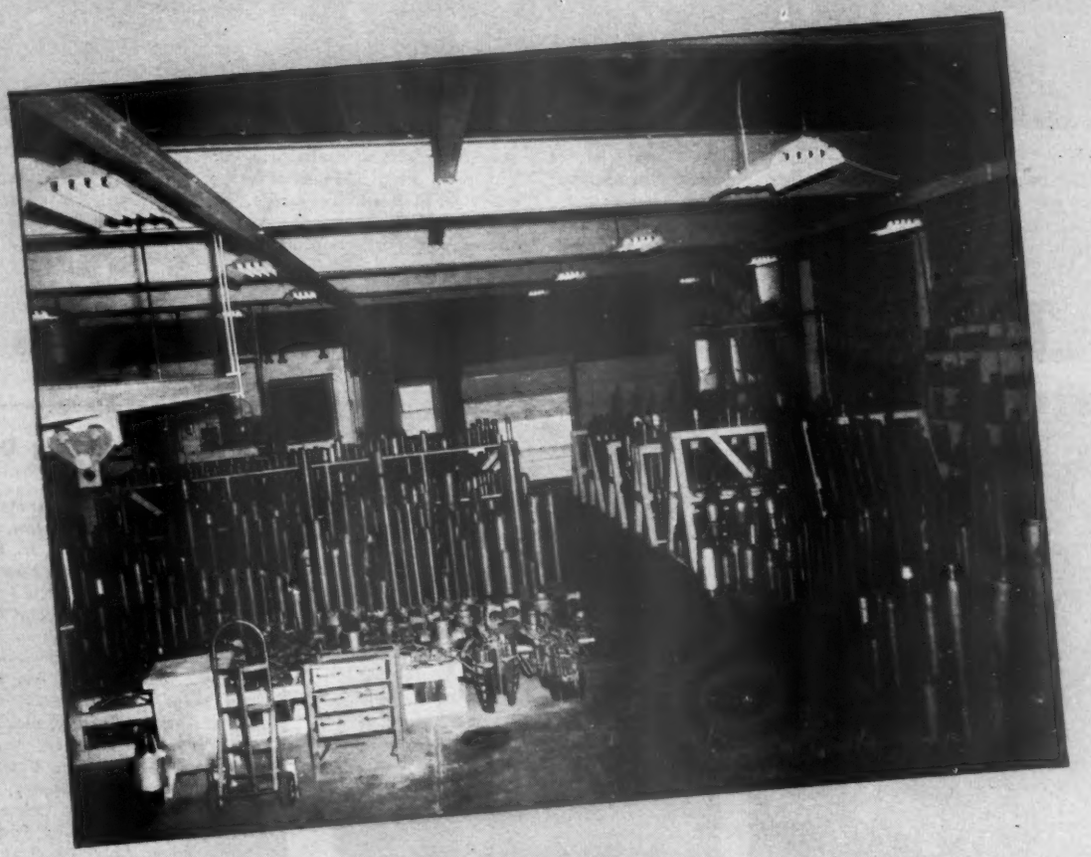

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NEW YORK: The annual invitation dinner of New York Chapter was given May 16 at the Hotel Biltmore. Herman Hickman, national sports figure, was the speaker. At the speaker's table, above, were: D. E. Kircher, deputy sergeant-at-arms; D. C. Washburn, assistant secretary; R. V. McIntire, senior regent; E. E. Andreason, sergeant-at-arms; General Baird H. Markham, toastmaster; S. D. Berkley, president; H. Hickman, principal speaker; H. E. Maland, vice president; D. L. Grill, treasurer; N. L. Boulden, Jr., junior regent; R. J. Faris, deputy sergeant-at-arms; W. E. Vilkman, assistant treasurer, of the New York chapter of Nomads.

THE OASIS—*A gathering spot for Nomads*

TULSA. At an evening meeting at Southern Hills Country Club, June 10, Gilbert Swift, president of Tulsa Nomads, is congratulated by Bob Glover, past president, on fine party, which was enjoyed by a large membership present.

GOLF TROPHY. P. C. Brase, U. S. Steel Export, receives the I. Frank Brown trophy from S. D. Beckley of Beckley, Haltom and Hickman. The trophy is awarded to low net golfer in New York.

Nomads Meeting Dates and Secretaries

New York Chapter, first Monday of the month, Biltmore Hotel, New York. Secretary, Maurice F. Delano, Jr., R. S. Stokvis & Sons, Inc., 17 Battery Place, New York 4, N. Y.

Houston Chapter, second Monday, Ye Olde College Inn, Houston, Texas. Secretary, H. Ben Young, Mission Manufacturing Company, P. O. Box 4209, Houston, Texas.

Los Angeles Chapter, second Wednesday, Jonathan Club, Los Angeles, California. Secretary, Earle R. Atkins, Emsco Manufacturing Company, P. O. Box 2098, Los Angeles 54, California.

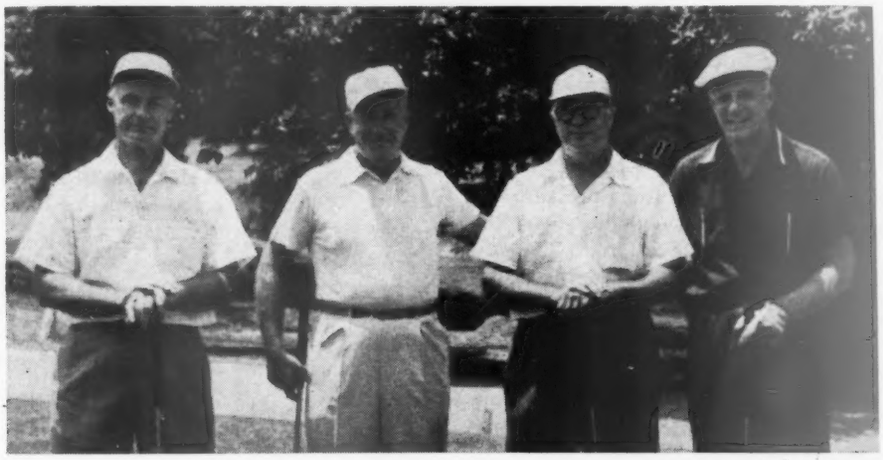
Tulsa Chapter, third Friday, "After Five," Room, Hotel Tulsa. Secretary, O. B. Irizarry, *Petroleo Interamericano*, 211 South Cheyenne, Tulsa, Oklahoma.

Dallas-Fort Worth Chapter, first or second Monday. Secretary, H. A. Davis, H. A. Davis Power Equipment Company, 2142 Irving Boulevard, Dallas, Texas.

INTERNATIONAL GUESTS at the June meeting of the Los Angeles Nomads in photo at left are: (standing) Alexander T. McKenzie, Overall McCray Pty Ltd., Australia; Nirat Samathapand, Department of Mines, Thailand; Jorge E. Malenchini, TIPSA, Argentina; (seated) V. W. Fletcher, Asiatic Petroleum; C. Ben Organ, Texas Company, Colombia; John F. Woodman, Iniskin Unit, Alaska. In photo at right are: (standing) C. M. Williams, Iraq Petroleum; Ben Coles, Creole, Venezuela; Patricio del Solar, ENAP, Chile; Tom Pearson, ex-Shell, Borneo; (seated) William Alexander, Jr., General Petroleum, Iran; I. J. Teitelbaum, foreign representative from Argentina; Robert Lazayres, SEREPT, Tunisia; Duane A. Schmeekle, Shell, Calgary, Canada.

LOS ANGELES: A Father and Sons meeting, June 8. Back row: M. L. Hamer and father, Nomad Hamer of Hamer Oil Tool; F. S. Hamer, another son; Nomad Collins of Hydril Company; Frank Atkins, son of Nomad Atkins; H. Rex Collins, Sr., father of Nomad Collins; Nomad Hunphreys of Axelson Manufacturing, and his son-in-law, Darrell Limoges; Bill Atkins, and father, Nomad Atkins of Emsco; Jim Doyle and father, Nomad Doyle of Hydril; Harry McLaren, son of Nomad McLaren. Middle row: Nomad Taylor of Bettis Rubber, and son, John; Nomad Merkley, National Supply, and son-in-law, Tom Turner; Nomad Schlarb of Chiksan Company; Harold Doane, Halliburton Oil Well Cementing; Nomad Page, Page Oil Tools; Nomad McLaren, Hughes Tool. Front row: Nomad Ennis, Oil Well Water Locating Company, and son-in-law, James MacDonald; Nomad Laird, Cardwell Manufacturing, and son-in-law, John Lyddon; Gary Schlarb, son of Nomad Schlarb; Steve Doane, son of Harold Doane; John Page, Jr., son of Nomad Page..

Robert Brown, Ideco Division, Dresser Industries (middle) was inducted into the Los Angeles Chapter of Nomads at the regular monthly meeting, June 8. To his right is Rex Collins, Hydril Company, ritual master, and left, Bob Gaylord, Wagner-Morehouse, Inc., sergeant-at-arms.



DALLAS-FORT WORTH: Golf was the order of the day June 24 at the Northwood Country Club, Dallas, Texas, when Nomads Frank Morrow, British-American Oil; Herschel Lewis, Emsco Manufacturing; Howall Adair, Sun Oil; Don Monnett, Magnolia, played a foursome.

Another foursome at the Dallas golf party were: Cecil Scott, Security Engineering; C. F. Bedford, Stanolind Oil & Gas; Bert Birnie, Security Engineering; Paul Randals, Keating Drilling.

Joe Kelly, Reed Roller Bit; Jack Mussler, Continental Supply; Sherman Hunt, Empire Drilling; Guy Williams, Seaboard Oil, stopped swinging their clubs long enough to pose at Dallas golf party.

EXPLORATION ACTIVITIES

LOUISIANA

★ A jointly owned Kerr-McGee and Union Co. of California well, marks the fourth field opened for Kerr-McGee in the Breton Sound and Main Pass Areas. The new discovery, State Lease 1268 Well A-1 block 47, Main Pass area, Plaquemines Parish, Louisiana, is located some 54 miles southeast of New Orleans on an 11,666-acre tract. Drilled to 8600 ft, the new oiler flowed 187 bbl per day on production tests from perforations at two levels, 8192-8201 ft and 8212-8218 ft. Operators indicate additional potentially productive sands could be tapped with further perforations. On a six-hour test, using 10/64-in. choke, the well produced 30.2 deg oil. Tubing pressure was 750 lb and gas-oil ratio 576 to 1.

★ Opening of a new Louisiana oil field on The Texas Company's Topsy Prospect came with completion of its W. E. Godwin No. 1, Jefferson Davis Parish. Well was initially gaged flowing 136 bbl of 29.7 deg of clean oil per day through a 11/64-in. choke. Drilled to a total depth of 8505 ft, the discovery well was brought in through perforations 6114-6125 ft in the First Frio. The tubing pressure was 400 lb, and the gas-oil ratio was 304 to 1. Nearest production to the new field is the Indian Village field, approximately four miles east.

CANADA

★ Canada-Cities Service Petroleum Corporation, reported today that production from its Easyford No. 1, in Alberta, Canada, will extend the Pembina field 1¾ miles to the northeast. The well produced 113 bbl of oil a day through a ¼-in. choke during a production test. The 39.8 deg oil is flowing from perforations in the Cardium formation between 4807-4827 ft after sand frac. Location of the well is in a 5745-acre block and is about 70 miles southwest of Edmonton, Alberta, Canada. Cities Service holds a 37.5 percent interest in the well and is operator. Joint owners in the venture are Seaboard Oil Company and Stanolind Oil Company.

PERU

Douglas Oil Company has spudded D-3-L in the Lobitos area, an offset to Compania Petrolera Lobitos' No. 414 which is bottomed at 6490 ft. Douglas recently completed their first successful test in this area.

TEXAS

★ Sterling Oil of Oklahoma, Inc's. No. 1 King well located in the Melchor Travieso in Haskell County has been completed for 144 bbl of oil and 82 bbl of water per day, from the Palo Pinto limestone. The well was drilled to a total depth of 3303 ft and encountered 13 ft of porous limestone with good saturation. Casing was set on top of the formation at 3290 ft with 100 sacks of cement and the well was cleaned out with 500 gal of mud acid and commenced flowing. This well is in a field confirmation to a discovery made last month by Pontiac Refining Company in co-operation with Sterling. The discovery well was drilled on the offset location to King No. 1. Sterling has moved 993 ft east of the King No. 1 and now drilling at 2690 ft. Pontiac has moved north of their No. 1 well 660 ft and 330 ft west of Sterling's lease line, and now drilling at 3110 ft.

★ The Cities Service-Skelly University AZ No. 1, a quarter-mile extension of the Emma pool, today reported a flow of 88 bbl of 48.7 deg oil during a one-hour drillstem test. Pipe is being run to complete the venture which is on a 960-acre block jointly owned by Cities Service and Skelly Oil Company. Drillstem test was made between 12,217-270 ft in the Ellenburger. Gas surfaced in 55 minutes and the 2500-ft water load in an hour. After cleaning to pits for 25 minutes the well made the reported flow. Gas-oil ratio for the production was 508 to 1. Location of the well on University Land in Andrews County and about 25 miles northwest of Odessa.

★ Monterey Oil Company has announced discovery of a condensate field in the Peters Ranch Prospect, located in Duval County, South Texas, where the firm holds a 776-acre parcel, lying some 65 miles west of Corpus Christi. The discovery well, W. R. Peters No. 1, is producing from an interval between 8712 and 8744 ft in the Wilcox sand, and is yielding a gas flow rich in condensate. The well's curtailed flow is 700,000 cu ft a day of gas that is testing 10 bbl of condensate per 1,000,000 cu ft with a tubing pressure of 4200 psi.

SUMMARY OF DRILLING ACTIVITY FOR AUGUST
(As Compiled by Rinehart Oil News Staff)

States	New locations		Wildcat completions			Field completions			Junked & abnd.		Temp. abandoned		Abandoned locations		Current active wells	
	Wc	Field	Oil	Gas	Dry	Oil	Gas	Dry	Wc	Field	Wc	Field	Wc	Field	Wc	Field
Alabama	2	0	0	0	1	0	0	0	0	0	0	0	0	1	2	0
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Arkansas	20	69	0	0	11	45	7	15	0	1	0	0	0	0	12	27
Canada (Williston B.)	24	73	1	0	9	35	0	4	0	0	0	0	0	1	17	26
Colorado	90	80	4	3	55	47	4	28	0	0	1	1	0	0	2	56
Florida	2	0	0	0	3	0	0	0	0	0	0	0	0	0	5	0
Georgia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kansas	1.0	331	21	5	101	204	43	105	0	0	0	0	1	8	76	317
Louisiana	49	235	3	2	31	191	34	53	1	1	2	4	0	15	92	290
North	16	111	0	0	11	119	19	27	0	1	1	3	0	12	18	54
South	29	111	1	2	17	60	13	20	0	0	1	1	0	2	53	208
Offshore	4	13	2	0	3	12	2	6	1	0	0	0	0	1	21	28
Mississippi	19	14	0	1	15	13	1	12	0	0	0	0	1	0	11	28
Montana	23	24	2	0	8	12	0	2	0	0	0	0	1	2	26	23
East	7	10	2	0	3	4	0	1	0	0	0	0	0	1	8	11
West	16	14	0	0	5	8	0	1	0	0	0	0	1	1	18	12
North Dakota	9	13	1	0	5	13	0	1	0	0	0	0	0	0	10	16
Nebraska	49	53	3	0	42	28	0	17	0	0	0	0	2	0	20	34
Nevada	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
New Mexico	41	171	2	9	14	96	45	9	0	0	0	0	1	1	7	51	177
Eastern	17	99	2	0	12	96	3	6	0	0	0	0	1	0	5	33	124
San Juan	24	72	0	9	2	0	42	3	0	0	0	0	0	1	2	18	53
Oklahoma	90	723	12	3	66	457	22	166	0	0	2	5	2	16	75	530
South Dakota	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Texas	583	1,536	71	27	351	968	55	230	3	3	11	13	11	39	508	989
East	28	74	1	2	32	31	10	10	0	0	1	0	1	0	30	79
Gulf Coast	51	138	12	13	31	65	12	35	1	1	1	2	3	0	41	101
North Texas	123	334	22	1	51	170	1	72	0	0	0	0	1	0	100	110
Panhandle	3	78	0	1	4	54	7	5	0	0	0	0	0	7	22	47*
South Texas	148	284	4	10	94	181	20	56	0	0	5	2	3	4	75	80
Offshore	1	0	0	0	0	0	2	0	0	0	0	0	0	0	4	2
Border Co.	28	81	8	0	26	58	0	8	0	0	0	0	2	6	30	69
West Central	113	145	11	0	31	60	0	24	0	0	2	0	0	3	62	51
West Texas	88	402	13	0	82	349	3	20	2	2	2	9	1	19	144	450
Utah	15	6	2	1	6	1	0	1	1	0	0	0	0	0	23	3
Wyoming	25	64	3	1	15	24	2	14	0	0	0	0	0	3	39	71
Totals: Jan.	766	2,636	108	31	673	1,618	197	479	4	2	14	14	26	85	878	2316
Feb.	798	2,931	93	30	630	1,745	144	548	4	7	17	22	34	126	877	2402
March	1040	3,535	91	41	674	2,133	219	623	4	11	16	26	19	107	863	2534
April	957	3,135	111	19	556	1,819	159	525	6	4	0	28	9	102	882	2551
May	1030	3,245	91	21	637	1,926	234	626	2	1	22	28	11	80	942	2590
June	1151	3,392	125	52	735	2,134	213	658	5	5	16	24	19	94	1017	2588
1955 Total	5742	18,874	719	194	3905	11,375	1166	3459	35	30	93	142	118	594	—	—

* Figure Incomplete.

Finding better solutions to the problems of reservoir evaluation and the refinement of these answers for economically feasible application is an endless process. Constant changes in drilling, completion, and production practices directly influence formation and fluid analysis procedures.

For example, as more wells are completed in very tight zones, the time required to obtain permeability and porosity data and its degree of accuracy have become critically important.

Aided by industry experiments, a Core Lab approach to these reluctant reservoirs is a new type centrifugal extractor designed to rotate up to 6500 RPM, forcing hot solvent to sweep out the residual oil and water content of small typical permeability plug samples. The net result — *more oil extracted in one-half hour than has been heretofore possible in one week by other methods. Greater accuracy and better service at less cost to the client.*

Core Lab's Research and Development Department accepts not only the new and unique problems of reservoir behavior but also maintains a constant program of improving its own standardized techniques and procedures. Combined with a growing back-log of experience contributed by thirty-two permanent area laboratories, this progressive attitude means more reservoir revenue for the industry through better reservoir engineering.

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Exploration

OREGON

★ Sinclair Oil & Gas is preparing to drill a wildcat in Lane County. The state has been attracting an ever increasing amount of wildcatting, but has yet to develop commercial production. Sinclair's test is located in logging country near Mapleton, Oregon.

★ Standard Oil Company of California has abandoned its Hoagland Unit 1 wildcat, located 10 miles southwest of Astoria, Oregon, and 70 miles northwest of Portland. The well was bottomed at 7101 ft.

NORTH DAKOTA

★ Lion Oil Company has an apparent oil field discovery in its Skarphol No. 1 well in Bottineau County, North Dakota. The well is located 12 miles northwest of the town of Bottineau and 7 miles east of the Northeast Landa field, the nearest previous production in North Dakota. It was drilled in conjunction with the Tomahawk Oil and Gas Company and was completed in the Mission Canyon formation with a flow of 16 bbl per hr on a ¾-in. choke, through perforations from 2971 to 2979 ft.

Lion and Tomahawk have scheduled the progressive drilling of 7 additional wildcat wells on acreage held by the company in Bottineau and adjoining counties.

★ Amerada Petroleum has confirmed production in the new Croff field of McKenzie County. The well, labeled the No. 1 Anderson, flowed 10 bbl per hr through a ¾-in. choke from perforations into the Madison lime at 9592-610 ft. Casing was set two feet off bottom, called at 9714 ft. The well is about one-half mile south of the discovery.

KANSAS

★ Cities Service is locating a rank test, the Heaton No. 1, approximately eight miles northeast of Norton, in Norton County. It will go to the Reagan sandstone, expected at approximately 3,750 ft. The Arbuckle dolomite will be tested on the way down. The test is on the company's 2880-acre East Norton block and is 14 miles northeast of the Norton (Arbuckle-Reagan) pool, nearest production.

COLORADO

★ The California Company has reported the first pump gage at its Lyons (Permian) sand discovery north of Pierce in Weld County. The well, Priddy 1, C NW SW 23-8n-66w, pumped 230 bbl of oil in 15 hours. Recovery was from 9201-10 ft, representing only a small portion of the total Lyons sand in which shows were found.

CALIFORNIA

★ Tide Water Associated Oil Company is drilling a gas test two miles west of Shafter in Kern County, and ¾ of a mile northwest of their gas discovery of last December. The well is Penner No. 37-7.

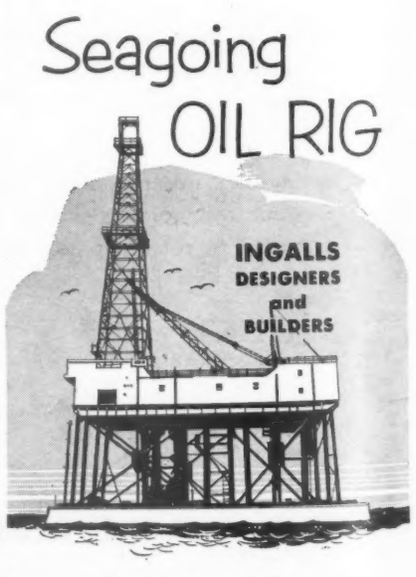
★ Another wildcat has been abandoned in the vicinity of the "let's try it again" Russell Ranch and Morales Canyon fields of Cuyama Valley. George J. Greer's No. 28-24, northwest of production, reported encountering several encouraging shows, but nothing commercial.

★ Intex Oil Company has completed Blodget & Crome No. 88 in the Grapevine-Tejon area for initial production of 1350 bbl per day of 35 deg clean oil. The well was drilled to a total depth of 7348 ft and was completed with perforations at 3 intervals: 7244-7260 ft, 7270-7287 ft, and 7295-7315, in the Jewett sand. The well gives Intex its first production in the Jewett.

★ Standard Oil Company of California is drilling a deep test two miles east of production in the South Belridge field, Kern County. The new venture, Van Wy No. 341, is expected to probe to around 13,500 ft.

★ The San Fernando Valley is in for another oil test. Intex Oil Company is preparing to drill a wildcat near the intersection of Highway 99, Foothill and Sepulveda Boulevards by the Los Angeles aqueduct. The well is to be known as Howell-Title Insurance & Trust Company No. 1.

★ Ridge Hill Oil Company made a new sand discovery in the Tejon area, Kern County, with the completion of Schoettler No. 12 at a total depth of 7150 ft. The well penetrated the JV gas cap after encountering the Freeman zone. Initial production was 45 bbl of 34 deg oil in 4½ hours, however, the flow died and the operators are preparing to install a pump.



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Exploration

CALIFORNIA

★ The Texas Company is preparing to drill two new wildcats. Lopes (NCT-1) No. 1 in the Fairfield area of Solano County, in Northern California, will explore for a new gas field discovery.

★ In the Camatta Canyon area of San Luis Obispo County, Texaco will drill Camatta Ranch No. 2, 12 miles south of Cholame and 4 miles northwest of a dry hole last winter on the same lease.

★ Sun Drilling Company is preparing to drill a deep test in Pleasant Valley a few miles northeast of Coalinga in Fresno County. No. 58-28 is located on land leased from the Pleasant Valley Farming Company.

★ Sunray-Mid-Continent Oil Company and Ohio Oil Company reported some encouragement on their wildcat located on the Kraemer-Del Cielo lease, 2½ miles northwest of Oxnard in Ventura County. During a one-hour shut-off test they recovered 8903 ft of clean 29.4 deg oil at 13,730 ft. Casing is set to 14,010 ft and it is expected that the operators will do some additional testing at the present depth before continuing drilling. It is not certain whether the oil show came from a section of the Sespe sand or whether it might be a new pool or an extension of Montalvo production to the west.

★ Continental Oil Company is preparing to drill a wildcat 3½ miles west of the Newhall-Petrero field in Los Angeles County where the company holds a block of about 3000 acres. The well is expected to explore to about 7000 ft.

★ Harry Long and O. R. Hedges made a new discovery in the Vallecitos area of San Benito County. On a formation test at 5232-5312 ft the well flowed at an estimated rate of 500 to 1000 bbl per day of 38 deg oil. The tester was open 70 minutes and oil blew over the crown. Production is reported to be from Eocene sand.

★ Patrick A. Dohney, Bankline Oil Company and Sunray-Mid-Continent will drill a joint venture wildcat in the vicinity of the southwest corner of Garfield and Slauson Avenues in East Los Angeles. They will look for production in the interval of the General Exploration Company production in the Bandini field 1½ miles northwest. Depth of the new test is expected to reach around 9000 ft.

★ Universal Consolidated has spudded a gas test in the Fairfield Knolls area of Yolo County. The well, Atkinson A-1 on Sec 2-, 9-1, is located one mile northwest of existing production.

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What's doing in DRILLING

★ Drillers have made nearly 120,000,000 ft of hole in the first six months of this year, our records show. This is more than any amount ever recorded in similar periods of past years.

★ The holes put down number 20,818. Although this is 800 more than drilled in the first half of 1954, we haven't set any all-time record.

★ All these figures indicate that we are drilling them deeper. According to Hughes Tool Company, we haven't used any record number of rigs to do it in, either.

★ Wildcats account for 4818 holes drilled this year. Nineteen per cent of this number were completed as oil or gas wells. Last year, according to Rinehart Oil News figures, the 4563 exploration ventures were about 17.5 per cent successful.

★ In Texas the wildcatters have tried 2300 times with only 12 per cent success. Last year they were about 18 per cent successful. It may be that this lower rate of discovery that has discouraged wildcatting in the Lone Star State, along with current low allowables.

★ Texas is in an exploratory slump, and it has a lot of people concerned. One of these is E. O. Thompson, of the Texas Railroad Commission.

★ Thompson says that this condition can't last long, however. "The wildcatter will bounce back." He gives credit to these men for bringing in over 80 per cent of all discoveries, and puts them in a "never-say-die" category.

★ Dad Joiner, who brought in the East Texas field in 1930, is the epitome of a wildcatter, in Thompson's way of thinking. Joiner was operating on borrowed money, and paying salaries in lease acreage, before the famous No. 3 Daisy Bradford blew in.

★ Could it be that wildcatting is no longer glamorous? Maybe there was something about seeing oil spraying over the crown block that is lacking in the wildcat drilling techniques of today. Thompson seems to associate all this with wildcatting.

★ Such flows, uncommon because of today's safety equipment, mud control and drilling techniques, aren't altogether a thing of the past. A look at this month's drilling reports show several oil finds which resemble the "gushers"of a few years back.

★ Harry Long and O. R. Hedges saw oil go over the crown on their test in the Vallecitos area of San Benito County, California. The well flowed at an estimated rate of 500 to 1000 bbl per day from the Eocene at a depth of 5232-5312 ft.

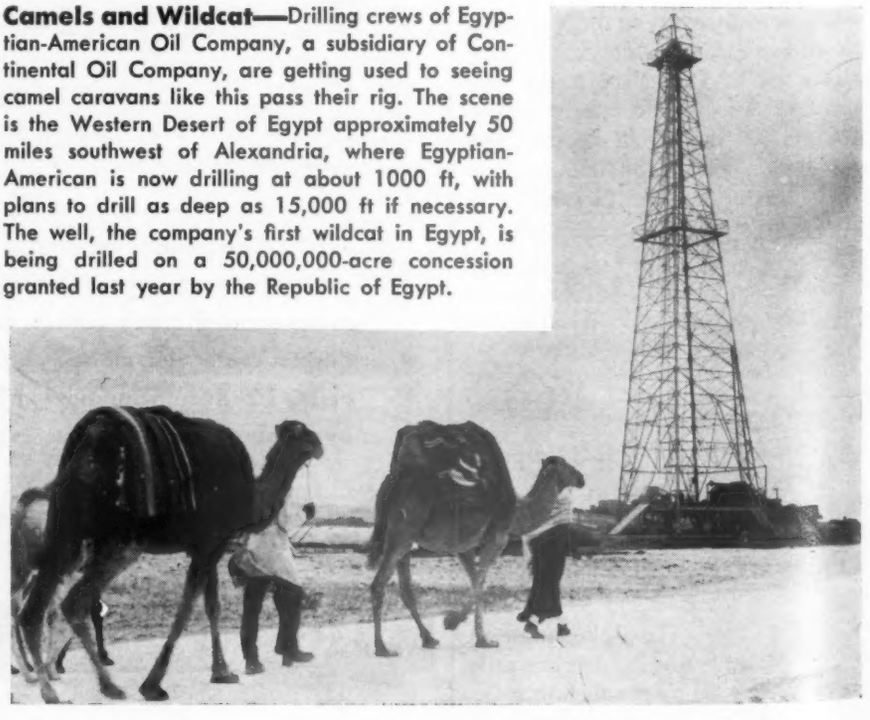
★ Amerada Petroleum Corporation had a spray of oil from the Simpson dolomite on test at the No. 1 Farris, an Anadarko Basin wildcat in Woods County, Oklahoma. A one-hour drillstem test was taken at 7425-42 ft, with 720-ft water cushion, flowing mud in five minutes and gas in 10 minutes calculated at 2,748,000 cu ft per day. Well sprayed oil in 20 minutes. Flowing pressure ranged from 1590 to 2040 psi and shut-in pressure was 3120 psi in 17 minutes. A similar flow was recorded on a test from the Simpson, called at 7380 ft, with sand at 7431 ft. Loffland Brothers, who have the contract on this well, were last reported coring at 7800 ft.

★ In the rough wildcat country of Bent County in southeastern Colorado, the M. J. Stansbury No. 1 Cordes-Overlander has been finaled successfully. During the drilling phase, a spray of oil plus an estimated 2 to 4,000,000 cu ft of gas was encountered on drillstem test at 4625-45 ft. On the initial test, 2,000,000 cu ft of gas were recorded from perforations into the sand, established as the Morrow, at 5208-27 ft. Nearest Morrow sand production is 65 miles southwest in Hamilton County, Kansas.

★ A well that attracted attention when it blew out while drilling, is Standard Oil Company of Texas' No. 2 Canon. The Pecos County wildcat, 10 miles southwest of Iraan, first blew out at 6696 ft from the Cisco. On a second test in the Cisco, the well surfaced gas in six minutes and mud in 18 minutes, and oil in one hour and 40 minutes. The well flowed 1.76 bbl of 33 deg crude in 90 minutes. Drill pipe was stuck and the well was killed with mud and recovery lost.

★ Another sad story was encountered at a wildcat venture in French Equatorial Africa recently. The Societe de Recherches et d'Explotation des Petroles du Cameroun, "Serepca" well blew out, with no blowout preventers available. Equipment was shuttled by air from Cameron Iron Works in Houston, Texas, to Dallas, then to New York City, Paris, and on to Douala before reaching the location. Such extended "supply lines" makes this kind

Camels and Wildcat—Drilling crews of Egyptian-American Oil Company, a subsidiary of Continental Oil Company, are getting used to seeing camel caravans like this pass their rig. The scene is the Western Desert of Egypt approximately 50 miles southwest of Alexandria, where Egyptian-American is now drilling at about 1000 ft, with plans to drill as deep as 15,000 ft if necessary. The well, the company's first wildcat in Egypt, is being drilled on a 50,000,000-acre concession granted last year by the Republic of Egypt.



DEEP-WELL CEMENTING calls for top-quality cement. Safeguard *your* "stake" by specifying Unaflo Oil-Well Cement. Careful quality control in Unaflo manufacture assures reliable performance in the field.

LABORATORY TESTS by skilled technicians check Unaflo Oil-Well Cement regularly throughout its manufacture, and also contribute a continuing research study of oil-well cementing. Because of this testing and research, oilmen can count on Unaflo for *consistent* high quality and *uniform* performance.

Successful cementing in the field

starts with quality control in the lab

You're *sure* of reliable field performance when you specify Unaflo* Oil-Well Cement because Unaflo is manufactured under rigid quality controls. Careful testing in the laboratory and during manufacture maintains *consistent* high quality. Shipments of Unaflo are tested by trained technicians to assure proper bottom-hole performance.

This consistent high quality pays off in the field. In time of emergencies, oilmen are sure of vital extra time because of Unaflo's *retarded* set. And Unaflo's slurries pump easily right from the start ...stay fluid and pumpable under critical conditions of temperature and pressure. Yet after the retardation period, Unaflo slurries form a strong, tight, sulphate-resistant seal.

When you're drilling deep and cementing slurries *must* go in place without a hitch—despite heat, pressure or unexpected delays—protect your investment by specifying Unaflo Oil-Well Cement.

FOR FURTHER INFORMATION, and typical data tables on Unaflo's bottom-hole performance, or for information on any of our other cements, write: Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, New York.

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Unaflo Retarded Oil-Well Cement
Resistant to Sulfate Waters

Atlas Portland Cement—Type I

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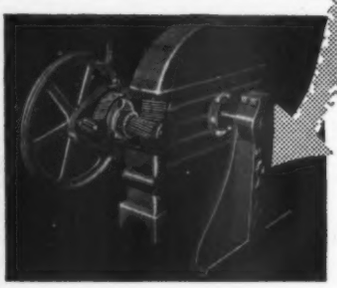
of service appreciated. It is the type that most drilling contractors enjoy in this country.

★ Falcon Seaboard Drilling Company of Tulsa, Oklahoma, recently received a note of appreciation from the citizens of Blackwell, Oklahoma. The letter was in recognition of and appreciation for aid given to assist in rehabilitation work following the recent tornado disaster.

★ Damage done by the January earthquake in Long Beach, California, is still being counted in the Wilmington oil field. First reports showed that 40 wells had stopped producing, and 28 damaged in the January tremor.

JENSEN JACKS



Lift MORE Oil at LESS Cost!

Avoid costly time-consuming breakdowns and continuous maintenance by standardizing on JENSEN JACKS. They have few moving parts — need practically no servicing. That's why JENSEN JACKS can lift MORE oil at LESS cost. Write us for more information... or see your JENSEN dealer.

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★ Redrilling costs in the Wilmington area has now been estimated to be about $3,000,000. Loss of oil from the wells rendered non-productive is around 2500 bbl per day. Three other major tremors have been recorded since 1947, with redrilling and remedial work cost totalling $21,250,000. It was in this area tha the bell-hole casing method was evolved, in which 7 or 8⅝-in. casing was run in a hole drilled to a diameter of 22 to 26-in. to correct for earth slippage.

★ Recent increase in the price of casing, as well as drill pipe and rig "iron," has many contractors contemplating adjustments in the price of drilling—the first of any significance in over two years.

★ This should just about be the last straw for the low-allowable conscious, government brow-beaten, cost-concerned operator. According to some reports, for instance, a 11,600 ft well in Louisiana requires 255 tons of casing and tubing, increasing the cost $3555 more than it was before July 6.

★ Question is: Can you milk a duck? If the producers can't pay an additional cost, the drilling contractors may be forced to search even harder to lower their own costs.

★ On the horizon is one possible solution: The sonic drill. Manufacturers have scheduled the instrument for commercial production in 1957. The drill is being developed by Borg-Warner Corporation, and is currently being tested in Ventura County, California.

★ Trans-Tex Drilling Company of Shreveport, Louisiana, has announced purchase of a $500,000 drilling rig, among the largest ever assembled in that area. First well slated is a 13,000 ft test for Union Producing Company, et al, in Hinds County, Mississippi.

★ A new firm, Coral Drilling Company, Inc., is completing designs for an offshore drilling barge. The corporation, which will specialize in off-shore operations, and headquartered in Fort Worth, Texas, is constructing a self-stabilizing elevated deck type designed to operate in up to 60 ft of water.

★ Harold L. Strader's Houston, Texas, drilling barge operating in Lake St. Clair, Canada, has been moving fast. The first exploratory well was bottomed at 3005 ft to confirm geophysical data for the area. From this test he moved his barge to a second location and spudded in in less than seven hours. Ten wells are slated for the area, just north of the U. S.-Canadian border.

★ Down south, Standard of Indiana has put out a release stemming from unconfirmed reports telling of a $10,000,000 exploration program for Cuba. This report indicates possible exploration there by one of its subsidiaries.

★ Exploration in Israel has been looking increasingly brighter, spurred by a report of the Israel-American Oil Corporation. An important gas strike has been announced in the vicinty of Petah Tiqua, on the Mediterranean side of the little country. A core hole, on reaching a gypsum section, identified as Miocene, at a depth of 3018 ft blew out and immediately ignited. This is the same stratum that produces oil in Iraq and Iran. Oil and gas traces have been recorded at shallower depths.

★ Gas wildcatting is also going on near Kingsville, Ashabula County, Ohio. Wooster Drilling Company, Wooster, Ohio, is doing the drilling, carried on with rotary tools. Locations are close to the south bank of Lake Erie.

★ Parker Drilling Company has completed Texaco's T. F. Cruse Fee No. 1 as an oil producer on the company's sales bulk station site at Hull, Texas. The well was completed as a dual producer in the Northeast Merchant field of Liberty County. Combined initial flow rate was set at 356 bbl per day, with the well bottomed at 9200 ft. As is usually the case, the oil must be moved by pipeline to refinery 75 miles away before being returned to the bulk stationed in processed form.

Rotary Rigs Operating in Oil Fields of United States and Canada*

	June 13	June 20	June 27	July 4
Pacific Coast	150	150	153	151
Oklahoma	347	341	326	336
Kansas	186	171	180	186
Rocky Mountains	255	251	265	273
Canada	167	184	195	203
Ark-La-Tex	180	188	174	159
West Texas and New Mexico	535	536	527	545
Gulf Coast	594	580	599	603
Illinois	135	148	155	143
North Texas	357	359	334	338
	2906	2908	2908	2937

*As reported to the American Association of Oilwell Drilling Contractors by Hughes Tool Company

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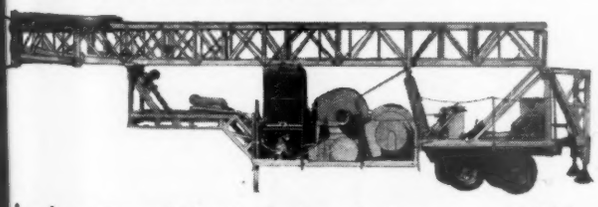
ON DEEP WELLS

MOGUL *Torcair* 42 Single or Double Drum Winch

CAPACITY: SERVICING WELLS TO 10,000 FEET With 2½-Inch Tubing, Without Hydromatic Brake — **SERVICING WELLS TO 16,000 FEET** With 2½-Inch Tubing, With 15" Double Rotor Hydromatic Brake . . . **AND NOTE THESE:** • **FULL AIR CONTROLS** • **FULL OIL BATH CHAIN DRIVES** • **LOWER DRUM BRAKE RINGS 42" x 8½"** • **WILSON QUALITY THROUGHOUT** • **TORQUE CONVERTER APPLICATION** —

Either a Torcon Torque Converter, Twin Disc or GM Converter can be used with any single engine Torcair Rig or Winch.



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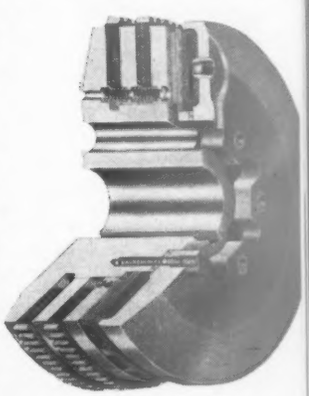
This type of clutch combines all the advantages inherent in air operation, such as convenient remote control, small manual pressure required for full torque, smooth starting and controlled torque. In addition, it gives freedom from self-engagement or reduced capacity, due to centrifugal force; and has much greater torque capacity than radial type air clutches. No packing to leak or let water or oil into the clutch friction surfaces. All air connections are on the outside and easily accessible. This without a doubt the finest clutch yet developed for this type service, providing great capacity in minimum space, no adjustments, practically impossible to burn up. **SMOOTHEST ENGAGEMENT OF ANY AIR CLUTCH!**



HYDROTARDER BRAKE APPLICATION

HYDROTARDER: The Mogul unit can be equipped with the 15" Double Rotor Type Hydromatic Brake driven by a chain drive from the countershaft. This brake can be used with either upper or lower drum, and when used on main drum with five lines strung up will absorb a total of 1300 H.P. when dropping the stands at the rate of 60 feet in 12 seconds. This is the equivalent of 16,000 feet of 2½" tubing. The brake is so arranged that it will absorb very little power when taking up the empty blocks and jaw clutch does not need to be disengaged to take up the empty blocks wnen the trip is completed.

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RUNNING TOUR with MEN in the INDUSTRY

Keith L. Rathbun, regional geologist for Continental Oil Company, has been promoted to manager of exploration for Conoco's western region, succeeding **R. M. Barnes** who was promoted to senior consultant. Promotion of **Richard B. Haines** from assistant regional geologist to succeed Rathbun has also been announced.

Rathbun has been associated with Conoco's geological activities since 1936 when he joined the company at Ponca City, Oklahoma. Barnes joined Continental in 1924 and has been active in the company's West Coast exploration for 31 years. Haines joined Continental in 1937.

Jack W. Hudson and **Harry Dernick** announce the formation of Production Management, Inc., with headquarters at 351 Colorado National Bank Building at Denver, Colorado. Hudson, the president, has been chief engineer, superintendent of drilling, and general superintendent for Deep Rock Oil Corporation.

Dernick, the vice president, was formerly district engineer, chief primary engineer and later assistant chief engineer in charge of oil and gas engineering and evaluation for Deep Rock. Previously, Dernick was employed by Republic Natural, Conroe Drilling Company, and Heep Oil Corporation.

James A. Waters, for the past 20 years chief paleontologist for Sun Oil Company, has joined the firm of Smith and Breyer, Corsicana, Texas. Waters is assuming duties as paleontologist and geologist for the firm, which concentrates its oil producing and contract drilling activities in a seven county area surrounding Corsicana.

J. A. Waters

Walters holds a BS degree from the University of Nebraska, and a MS degree from the university of Oklahoma, and has also done graduate work at Harvard University. Prior to his service with Sun he was chief engineer for the Mexican Eagle. He has served as president of the Cushman Foundation for Foraminiferal Research, and holds membership in several geological, geophysicial and technical organizations.

Appointment of **Charles E. Webber** as technical adviser to **John G. Pew,** Sun Oil Company vice president in charge of production, was recently announced. **William Abnett** was named assistant technical adviser. He formerly was special assistant to the late **James E. Pew,** manager of Sun's natural gas division in which Mr. Webber served as assistant manager.

Webber, a graduate of Louisiana State University, was assistant director of the Petroleum Administration for War's Natural Gas and Natural Gasoline Division in October, 1954, when he was named assistant manager of Sun's natural gas division. In 1951 he was on nine months leave of absence from Sun Oil to return to Washington as director of natural gas production and processing division of the Petroleum Administration for Defense.

B. F. Whitehill

G. A. Dow

J. P. McHugh

P. M. Konkel

WDM Oil Corporation has been formed with **B. F. Whitehill** as president, **G. A. Dow** as vice president, and **J. P. McHugh** as secretary-treasurer. The three are all from Tulsa, Oklahoma. Whitehill was formerly assistant to the president of the Whitehill Oil Corporation. He has been closely associated with extensive secondary recovery work conducted by that company. Dow has been contract representative for Midwestern Drillers, Inc., in Tulsa. McHugh has for the past four years been geological engineer and geologist for Keener Oil Company concentrating in exploration and development of primary and secondary reserves.

R. D. Michaels will be in charge of operations for newly acquired properties of the Crescent Corporation (formerly Deep Rock) at Ellinwood, Kansas. The properties, in Barton County, were purchased from W. L. Hartman.

Midland, Texas, Oil Scouts Association has elected **John Carmichael** of Sun Oil Company as president for the coming year. Others in the new slate of officers include **T. L. Huddleston** of Lone Star Producing Company as editor-in-chief of the organization's publication; **Benny Stephens** of Stanolind Oil Company, secretary-treasurer; **Elmer Barnett** of Standard Oil Company of Texas, second vice president, and **Jim Riggs** of Atlantic Refining Company, first vice president. **Jerry Roberts,** of The Superior Oil Company, is retiring president.

Fred H. Carr, formerly district geologist for the British-American Oil Producing Company in Casper, has been promoted to division geologist at Denver. **Thomas W. Bibb** will replace Carr as district geologist in Casper.

C. B. Heartwell has been appointed superintendent, gas and natural gasoline division, southern district, producing department, for Standard Oil Company of California. He succeeds **G. C. McLaren** who has retired after more than 38 years of service with the company.

Wayne L. McCann and **R. Lee Rogers, Jr.,** of Shreveport, Louisiana, have joined as partners in a petroleum consulting firm effective July 1, 1955. McCann, a registered petroleum engineer, has been a constultant since 1953, formerly having served as district engineer for Stanolind in Shreveport. Rogers, a geology graduate of the University of Arkansas, was formerly employed by Stanolind in their Shreveport office and is now resigning as district geologist for the Murphy Corporation to form the partnership with McCann.

Philip M. Konkel has been appointed assistant chief geologist for The Ohio Oil Company. Since 1950, he has been assigned to special geological and geophysical studies on the staff of the chief geologist at the general office in Findlay, Ohio.

Jack L. Battle, Humble Oil and Refining Company, Houston, Texas, has been elected vice-chairman of technical group committee T-1 on corrosion in oil and gas well equipment of the National Association of Corrosion Engineers. He is supervising chemical engineer in the production department of Humble Oil and Refining Company. Mr. Battle also is chairman of T-1H on oil string casing corrosion.

The appointment of **R. A. Cruickshank,** of Regina, Saskatchewan, Canada as vice-chairman of the board of governors of the Canadian Petroleum Association has been announced. **Cruickshank** is director and general manager of Canadian Devonian Petroleums Limited. He graduated in law from the University of Saskatchewan and for a number of years was a partner in the Regina law firm of Balfour, Davidson and Cruickshank, prior to joining Canadian Devonian in March, 1952.

Tom E. Turner, formerly district geologist for Stanolind Oil and Gas Company at Salt Lake City, Utah, has resigned to open offices as a consulting geologist in that city.

Dr. John C. Calhoun, Jr., has been named dean of engineering for Texas A and M College. He will come to Texas from his present position as professor and head of the department of petroleum and natural gas engineering at Pennsylvania State University.

J. C. Calhoun

Dr. Calhoun is nationally recognized as a professional consultant, particularly in the field of secondary recovery, and is the Pennsylvania member of the Interstate Oil Compact Commission and a member of the engineering committee for the commission. He is also a member of the Penn Grade Crude Oil Association's technical advisory committee, chairman of the Mineral Engineering Division of the American Society for Engineering Education and has served as an independent consultant to many national oil producing and exploration companies.

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New Services • • • New Tools • • • New Methods • • • Outstanding Results

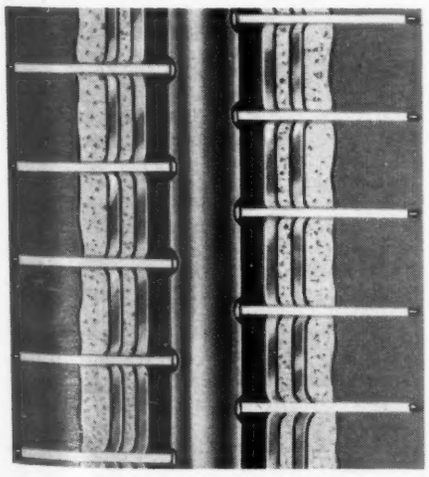
Uniform Hole Pattern in Casing Plus Deep Penetration Means More Barrels of Oil

Among the many benefits of M-3 Bullet Perforating is the uniformity of hole pattern in the casing. This perforating pattern is the same as the chambers in the gun itself. Shots are placed in patterns of staggered rows. This permits the safe use of more holes per foot in the casing, assures complete, uniform coverage of the productive zone, provides maximum drainage area from the formation and eliminates the possibility of bunching all shots in one area in the casing.

A fine example of effective perforating by M-3 Guns was recently reported from Wyoming.

Five inch O.D. 18 lb. liner had been set through the pay at 4300′ and was perforated by another service company for 60 barrels of oil per day.

McCullough reperforated with 204 new ½" Burrless Ogival Bullets in three hours rig time. Well was put on the pump for 260 barrels per day—over a 300% increase in production—and has maintained this production after being on the pump for some time.



Improved McCullough M-3 Bullet Perforators fire one to six shots per foot, one to ninety at a time and are placed exactly where they are wanted. Uniform hole pattern plus deepest penetration assures more effective drainage of pay zone—More Oil!

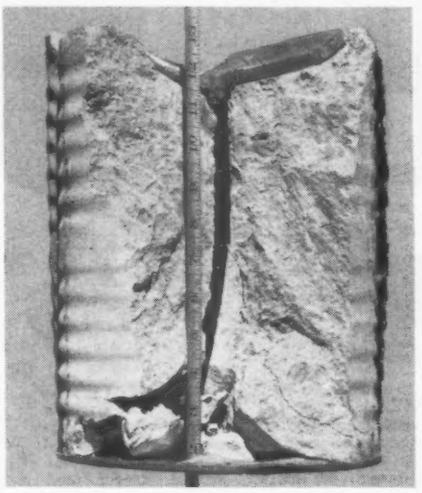
M-3 Bullet Guns Increase Production From 13,000 CF/D to 8 Million CF/D

Deep Penetration Through Thick Cement Sheath Increases Gas Production to 615 Times Previous Rate

The outstanding penetrating ability of improved McCullough M-3 Bullet Perforators was responsible for a startling increase in gas production from a Colorado well, according to a recent job report from the area.

Gas zone was located between 5349′ and 5395′. Open hole, in the pay interval, was calipered at 13". 7" O.D. 23 lb. casing was set and cemented through the zone.

This zone had previously been perforated by another service company using the permanent type well completion method, and the well made 13,000 cu. ft. of gas per day.



7" O.D. 26 lb. N-80 casing set in cement and perforated by 4¼" O.D. McCullough M-3 Bullet Perforator. Test sample was standing on a steel plate and ½" Burrless Bullet penetrated entire depth of target and ⅜" into steel plate.

McCullough was called to re-shoot the same zone. Made five runs with improved McCullough 4¼" 20-shot M-3 Guns and fired 184 ½" Burrless Bullets in the 46′ gas zone. A considerable increase in gas pressure was recorded after each run. After perforating was completed, the well tested at 8 million cu. ft. of gas per day and has continued to be a good producer.

Penetration like this is not out of the ordinary. M-3 Guns firing the new ogival bullets are capable of penetrating as many as three strings of cemented casing and deep into the productive formation. They give you premium penetration at no extra cost—they get the kind of results you want—greater production with maximum economy.

M-3 GUN PENETRATES CEMENT LEFT BY FIVE SQUEEZE JOBS

Five and one-half inch 17 lb. casing had been set through pay at approximately 6386′. Well had been squeezed five times to obtain W.S.O., leaving a great deal of cement to be penetrated.

Two different makes of jet perforators were fired at the desired depth without results. An improved 4⅛" O.D. McCullough M-3 Bullet Gun fired four shots in the same interval and made a well of 125 barrels per day. Time on job: One hour.

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To obtain more information on products advertised see page E-27

Running Tour

▸ **Sherwood Buckstaff,** manager of Shell Oil Company's exploration department for the Houston, Texas, area, has been appointed to the firm's head office exploration department to carry out a special assignment in Houston.

Buckstaff joined Shell in 1925 as a geologist in Wichita Falls, Texas. In 1944 he was named exploration manager for the Tulsa area. He took up his present position in 1948.

Sutton Metz, manager of the Midland, Texas, area exploration department, will replace Buckstaff as exploration manager in Houston. Metz joined Shell as a field geologist in San Antonio in 1937. He became exploration manager for the Calgary area in 1949 and was named to his present position in 1951.

George Corey, division exploration manager for the Midland area, will be advanced to the post of exploration manager, Midland area. Corey, who joined Shell in 1937 as a field geologist in San Antonio, was promoted to area geologist in Midland in 1949. He has held his present position since 1954.

▸ Two veteran Gulf Oil Corporation employees were recently retired. **George H. Lacy,** chief civil engineer, Houston division, completed 33 years with the company, and **Lowber B. Snow,** staff advisor, Houston division, had been with Gulf for 36 years.

Lacy started with Gulf at Houston in 1917, worked one year and resigned, returning to the company in 1922. Employed as a draftsman, he became a field engineer, then assistant chief civil engineer in 1931, before being promoted to the position of chief civil engineer in 1941.

Snow began his Gulf employment in Tampico, Mexico, in 1919 as an assistant civil engineer for the Mexican Gulf Company, a Gulf Oil Corporation subsidiary. In 1922, he moved to another subsidiary, Venezuela-Gulf, and in 1925 was named assistant chief civil engineer of Mexican Gulf. He became a field engineer for the parent company in 1929, and in 1950 he was named special assistant to the general manager of the Gulf Coast district.

G. F. Getty, II

Emil Kluth

▸ **George F. Getty, II,** is the new executive vice president of Pacific Western Oil Corporation, to succeed **Emil Kluth,** who has retired from active duty after almost 40 years' continuous service with enterprises of the Getty family. The new executive vice president is the son of **J. Paul Getty,** president of Pacific Western Oil Corporation.

Kluth was employed by the late **George F. Getty** in 1916 and was recognized as one of the first petroleum geologists active in American oil explorations. His first assignment was with the Minnehoma Oil Company, then a small, independent producer, principally in the Osage and Cleveland districts of Oklahoma.

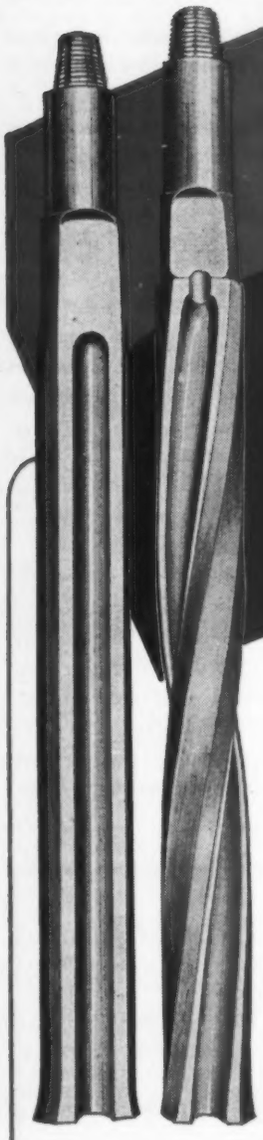
▸ D. D. Feldman Oil and Gas has announced that **Roger Henquet** will be in charge of exploration in Europe and the Middle East with offices in Paris, France. Henquet, a graduate petroleum engineer and geologist, set up and started operations in Houston, Texas, for the Schlumberger Corporation and served in the capacity of executive vice president and general manager for more than six years. He then became manager of European and Middle Eastern operations for The Superior Oil Company for three years, before forming his own organization in Paris, the Societé d'Etudes Petrolieres, in which he has been actively engaged since that time.

▸ Humble Oil & Refining Company recently announced the following changes in its production department supervisory personnel.

R. E. Bridges, division superintendent, Gulf Coast division, was promoted to assistant manager, production department, replacing **Bowman Thomas,** who resigned. **R. K. Tracy,** assistant division superintendent of the Gulf Coast division, succeeded Bridges as division superintendent.

T. J. Fuson, assistant chief petroleum engineer, was named assistant division superintendent of the Gulf Coast division. **C. W. Armstrong, Jr.,** district petroleum engineer, North Katy district, Gulf Coast division, was promoted to assistant division petroleum engineer, North Texas division. **M. H. Buchanan,** Odessa district transportation foreman, West Texas division, was transferred to the Goose Creek district in the Gulf Coast division as district transportation foreman. **Isaac L. Lundell,** senior district clerk, Lovell Lake district, Gulf Coast division, was promoted to chief clerk, petroleum engineering division marine equipment section.

Here's why-



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1. SPANG BITS are DIE-FORGED. Die-Forging assures uniform section throughout with the correct amount of reduction from billet to finished product, and better grain structure through the entire length of the bit. Result: *More footage. Lower cost.*
2. SPANG BITS are COMPLETELY HEAT-TREATED from end to end. *Complete* heat-treatment assures maximum grain refinement from pin end to drilling end. That means *stronger pin collars and blade sections* . . . fewer failures, even in hardest foundations.
3. The BLADE SECTIONS of SPANG BITS, designed for maximum penetration in hard formations, have ample water course to provide more room for cuttings and faster drilling action in sticky formations.
4. SPANG BITS are furnished with *semi-dressed drilling ends* which permits a bit to be dressed out to gage in less time and with fewer heatings.
5. SPANG BITS are *available in high carbon* and two grades of *alloy steel* to enable the user to select the quality of steel most suitable for his drilling conditions.

These five features, plus others, are reasons why for over half a century, SPANG Heat-Treated Drilling Bits have consistently produced more footage at lower cost.

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"Research is done in the mind." So claims C. G. Kirkbride, president of Houdry Process Corporation, before the American Society for Engineering Education in Philadelphia. Engineers should not be trained specifically for research or any other "niche" in industry, Kirkbride said; they should be trained broadly so as to be prepared for any field of endeavor. Too much has the engineer been trained in 'robot intellectually', too much standardization; too much attention to absorbing factual knowledge rather than learning to "think imaginatively." Inductive reasoning is a method of thinking for free people; it is ready for intensive development not only along scientific and engineering lines, but also in political, social and economic phases of life in the United States.

"The engineer of tomorrow," says Kirkbride, "must grapple with problems that the engineer of today has been unwilling if not unable to face. Develop his sense of proportion; give him training in the application of his imagination." Much food for thought, and work, in these statements.

★ ★ ★

Kerr-McGee mines uranium. The first oil company to mine and process uranium ore, Kerr-McGee Oil Industries, Inc., held open house at its Shiprock, New Mexico, uranium processing plant, completed recently at a cost of $3,000,000. Located on the Navajo Indian reservation, almost half the 100 plant employees are Navajos, and the ore processed comes largely from mines on this reservation. Mill uses an all-acid process for making uranium oxide. Nine mills have been put into operation in this, the Colorado Plateau area, where all U. S. uranium mills are located. Manager of mining and ore processing is V. L. Mattson, formerly Research Institute of Colorado School of Mines director.

★ ★ ★

Recycle stock for diesels? New methods for the utilization of cracked stocks as diesel fuel have been worked out, says Dr. L. A. Blanc of Caterpillar Tractor Company's research department, that make these formerly by-product materials far more useful and valuable than heretofore. Four main problems were faced, and Cat scientists and many others in the refining industry have aided in solving these difficulties. They are: Minimization of gum formation in storage; development of flow and spray characteristics to meet requirements of diesel fuel systems; production of cetane numbers high enough to permit proper combustion, and the elimination of problems derived from lubricating oils by lube quality and oil changes at proper intervals. Cracked distillate fuel use has been promoted by the development of improved lubricating oils.

★ ★ ★

More chemicals from petroleum. The oil and gas industry will produce 50 per cent of the total U. S. chemical production by 1965, said Shell Chemical's J. P. Cunningham, talking to the World Petroleum Congress in Rome. Production of butadiene, styrene and synthetic rubber under the pressure of war's demands was one of the major factors in starting and promoting this remarkable advance in organic chemistry.

★ ★ ★

New Sunoco gasoline. Sun Oil Company bangs the gavel on a 'new' motor fuel, after announcing one new fuel more than a year ago. Refinery facilities used to produce the new fuel include two new Houdriflow cat crackers at Marcus Hook, Pennsylvania, and Toledo, Ohio, refineries, each of 30,000 bbl per day capacity and an 18,000 bbl per day Houdriformer (cat reformer) unit at Marcus Hook. These three units cost approximately twenty-five million dollars. Sun also has taken on a new tanker, with another scheduled to be delivered soon. Expansion expenditures for 1955 are scheduled to total $75,600,000 compared to $64,-100,000 in 1954.

★ ★ ★

New chrome-nickel alloy. A new steel alloy, called HF grade, containing about 21 per cent chromium and 10 per cent nickel, that can serve in place of 25 Cr-12-Ni, more expensive alloys, has been brought by research at Battelle Memorial Institute, the American Society for Testing Materials was told at its annual meeting in late June. The new product will serve in the temperature range of 1200 to 1600 F satisfactorily, avoiding the necessity for higher Cr-Ni alloys of higher cost. Above 1600 F alloys of more than 30 per cent total alloying metals must be used.

100 octane number motor fuel—1965. Made possible largely by the development of catalytic cracking and reforming of heavier oils and of low-grade naphthas, the prospects are that the average motorist can buy 100 octane number gasoline in any filling station by 1965, according to present trends. Engine compression ratios now range from 7:1 to 9:1; in ten years these ratios will rise to 10:1 and up to 12:1. With the latter ratio, octane ratings of as high as 105 will come, say leaders in the refining and automotive fields. Gasolines of the premium grade are now sold in some areas that show 98 octane number.

★ ★ ★

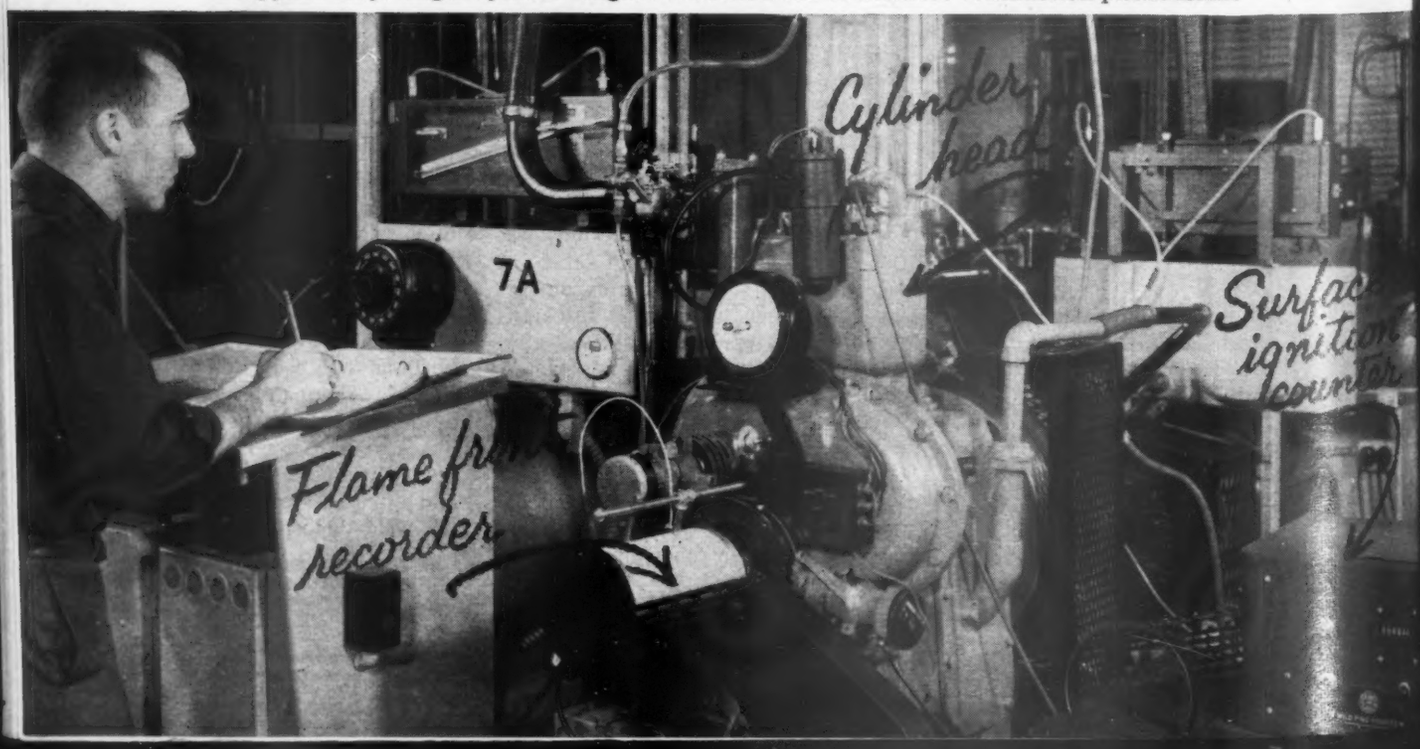
Contract for British Petrochemical Plant. Stone & Webster Engineering Corporation has announced its receipt of a contract from British Petroleum Chemical, Ltd., for the design and construction of ethylene, ethanol, and tetramer units costing approximately $13,000,000 (if built in U. S.) at Grangemouth, Scotland. These new high-capacity, high-efficiency units are an expansion of the company's original petrochemical plant completed in 1951. It was also designed and constructed by Stone & Webster and its subsidiary, E. B. Badger & Sons, Ltd. Ethylene will be used as raw material by the ethanol unit where synthetic ethyl alcohol will be produced. The tetramer unit will provide one of the necessary raw materials for the detergent alkylate unit currently being designed and built for British Petroleum Chemicals, Ltd., by Stone & Webster.

★ ★ ★

New alloy fluxes. The Lincoln Electric Company of Cleveland, Ohio, has introduced a new line of agglomerated fluxes for automatic submerged arc welding of low alloy steels. The method, claimed to be a new approach to the problems of welding complex and highly specialized steels, is said to be both economical and flexible in meeting the wide range of special requirements in welding these steels. By blending basic alloy fluxes in varying proportions with each other, The Lincoln Electric Company plans to produce automatic submerged arc welding fluxes to individual customer requirements. The basic fluxes will be stocked, and after the job analysis determines the weld deposit requirements, a flux can be created without delay to meet the specific requirements.

Experience with high-performance fuels in the famous 17.6 engine helps relate deposit problems to combustion-chamber design.

A typical Ethyl single-cylinder engine instrumented to measure combustion phenomena.



Lower engine octane requirements sought by Ethyl Research

One benefit of this program is the new more effective MOTOR PLUS

How to put the brakes on octane requirement increase has long been of great interest to us at Ethyl Corporation. We maintain a continuous research program on the subject.

Today, through experiments with a variety of modified single-cylinder engines, we are making significant new progress.

Now for the first time it is possible to reproduce in a single-cylinder laboratory engine the performance of a typical cylinder in a modern high-performance automobile engine on the road.

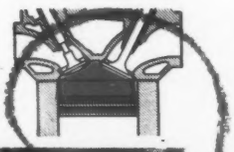
Here's how we went about it. Through the co-operation of car manufacturers, we made special cylinder heads for our single-cylinder test engines. These heads typify those currently used in many passenger cars.

Then to reproduce passenger-car performance, we developed operating schedules in which speed and load are varied automatically so that these chambers will build up the same type of deposits as those developed in a multicylinder engine on the road.

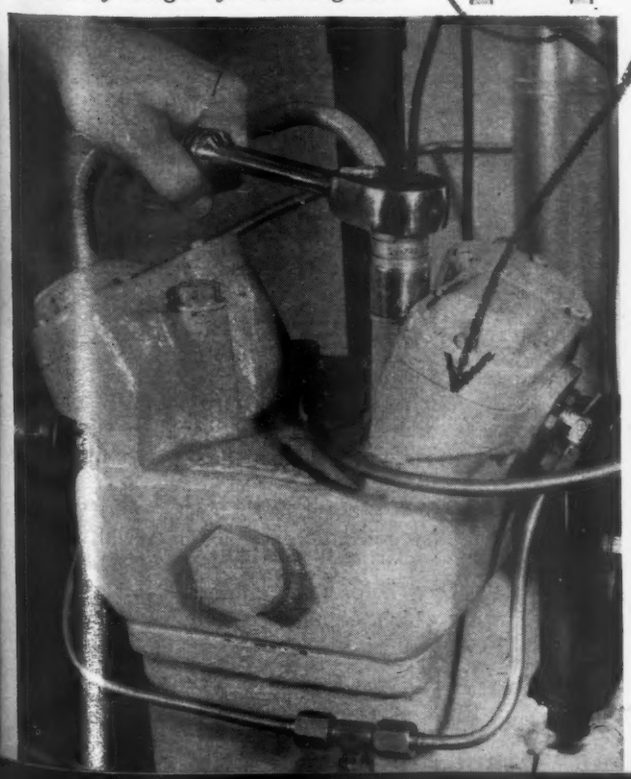
The accurate control and typical passenger-car-engine environments of these "new" Ethyl single-cylinder engines now enable us to gather previously unavailable information on the effects on octane requirement increase of fuel composition, oil composition, operating conditions and the effects of new additives. With the help of these engines, we developed Ethyl's new MOTOR PLUS, the improved TEL formula that reduces octane requirement increase on the average from .5 octane number up to 1.3 octane numbers.

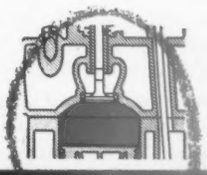
Our work in this field continues. We mention it here only as an example of what Ethyl Research is doing to help our customers. If you would like more information on this or any other Ethyl Research project, just call your Ethyl representative.

ETHYL CORPORATION
Research Laboratories
1600 West Eight Mile Road, Ferndale 20, Michigan
2600 Cajon Road, San Bernardino, California

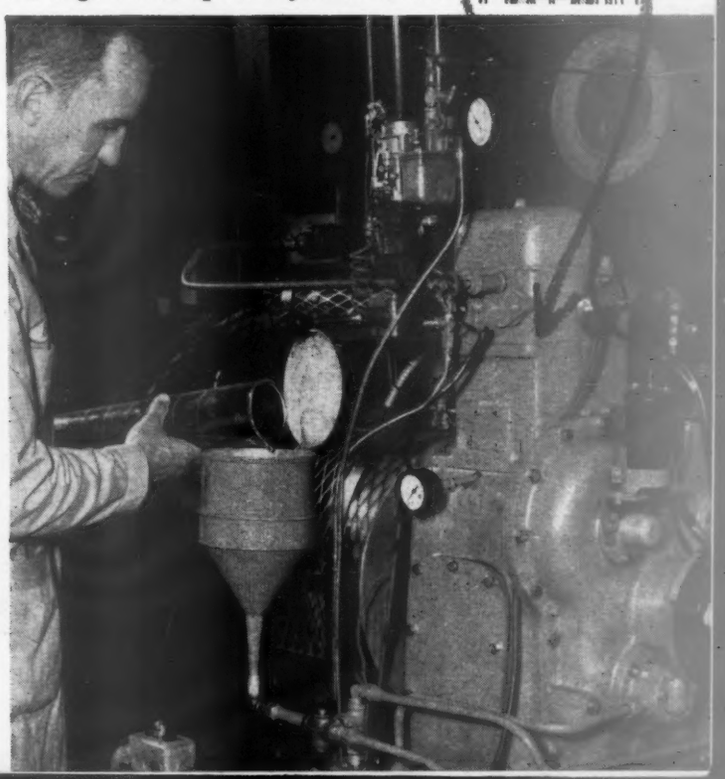


One type combustion chamber used in a popular make of cars is reproduced on an Ethyl single-cylinder engine.





Engine design of another leading car maker is reproduced on a single-cylinder test engine with special cylinder head.



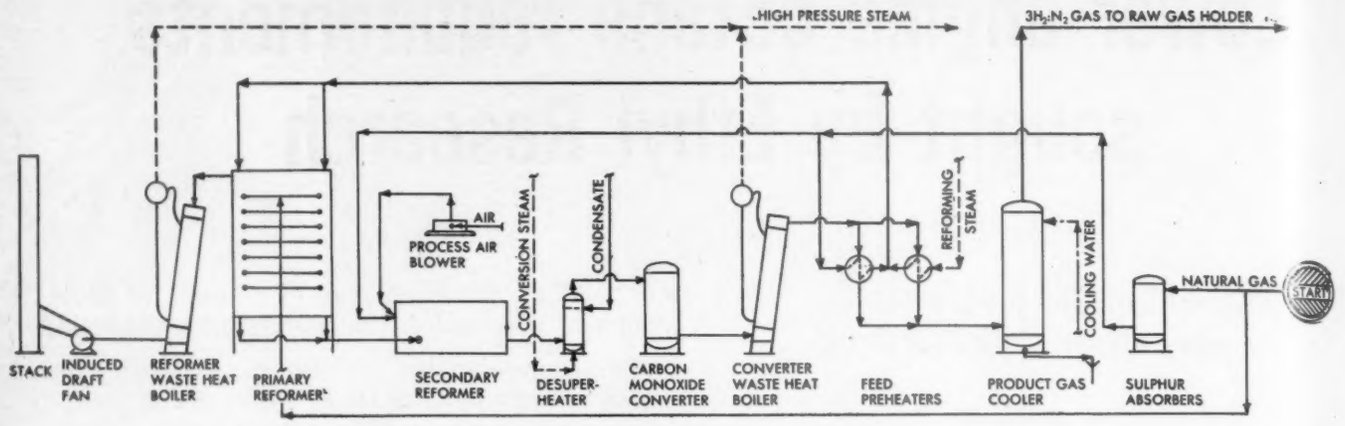


FIG. 1. Flow chart of ammonia synthesis gas process, South Point, Ohio, plant.

Natural Gas Reformers for Ammonia Synthesis

Lower costs, greater operating flexibility, and simplification of control led company to switch from coal to natural gas

R. J. Williams
Gas Processing Division, Girdler Company

NITROGEN division of Allied Chemical and Dye Corporation has shifted from coke to natural gas as raw material for producing ammonia synthesis gas at its plants in Hopewell, Virginia, and South Point, Ohio. At the present, about 85 per cent of the total United States output of ammonia is based on natural gas as the starting material .

When natural gas became available, Nitrogen division made the change because of considerably lower synthesis gas production costs. Other advantages stemming from the change include a decrease in the cost of compressing and purifying the raw synthesis gas because of the lower carbon dioxide content, greater operating flexibility and simplification in control of the synthesis gas composition.

The process for producing ammonia synthesis gas at the South Point, Ohio, plant is shown in Fig. 1. The process at Hopewell differs from that at South Point with respect to the manner in which conversion steam is added and heat recovery from the converted gas is effected.

Natural gas is purified of sulfur compounds by passing over activated carbon in the sulfur adsorbers. A portion of the natural gas and the reforming steam is preheated to about 500 F by heat exchange with the gas from the converter waste heat boiler in the feed preheaters. The preheated gas and steam are mixed and fed to the primary reformer where the gas-steam mixture is reacted to produce a hydrogen-rich gas.

The principal reaction, $CH_4 + H_2O = CO + 3H_2$, is carried out at a temperature of about 1400 F over a nickel catalyst contained in the alloy steel tubes in the primary reformer. The heat required for effecting the reaction is supplied by burning natural gas in the reformer furnace. Bunker C fuel is used for standby firing when the natural gas supply is curtailed. A reformer waste heat boiler is used for recovering heat from the hot flue gases from the primary reformer furnace.

The hydrogen-rich gas mixture, which still contains some unreacted methane, flows from the primary to the secondary reformer. Nitrogen required in the synthesis gas is supplied by burning the remaining portion of purified natural gas with air in special burners in the secondary reformer. The hot products of combustion from these burners mix with the hydrogen-rich gas from the primary reformer and pass to the nickel catalyst bed in the secondary reformer at a temperature of about 1750 F.

Substantially all of the methane in the primary reformed gas is reached in the secondary reformer. The reformed gas, consisting of a mixture of hydrogen, nitrogen, carbon monoxide, carbon dioxide, residual methane, argon, and water vapor, leaves the secondary reformer at about 1500 F and is cooled to about 900 F by adding conversion steam and condensate in the desuperheater. The gas then enters the carbon monoxide converter.

In the carbon monoxide converter steam reacts with carbon monoxide over a water gas shift catalyst to produce hydrogen and carbon dioxide. The converted gas then passes through the converter waste heat boiler and feed preheaters for heat recovery and is cooled by direct contact with cooling water.

The product ammonia synthesis gas, which contains carbon dioxide, car-

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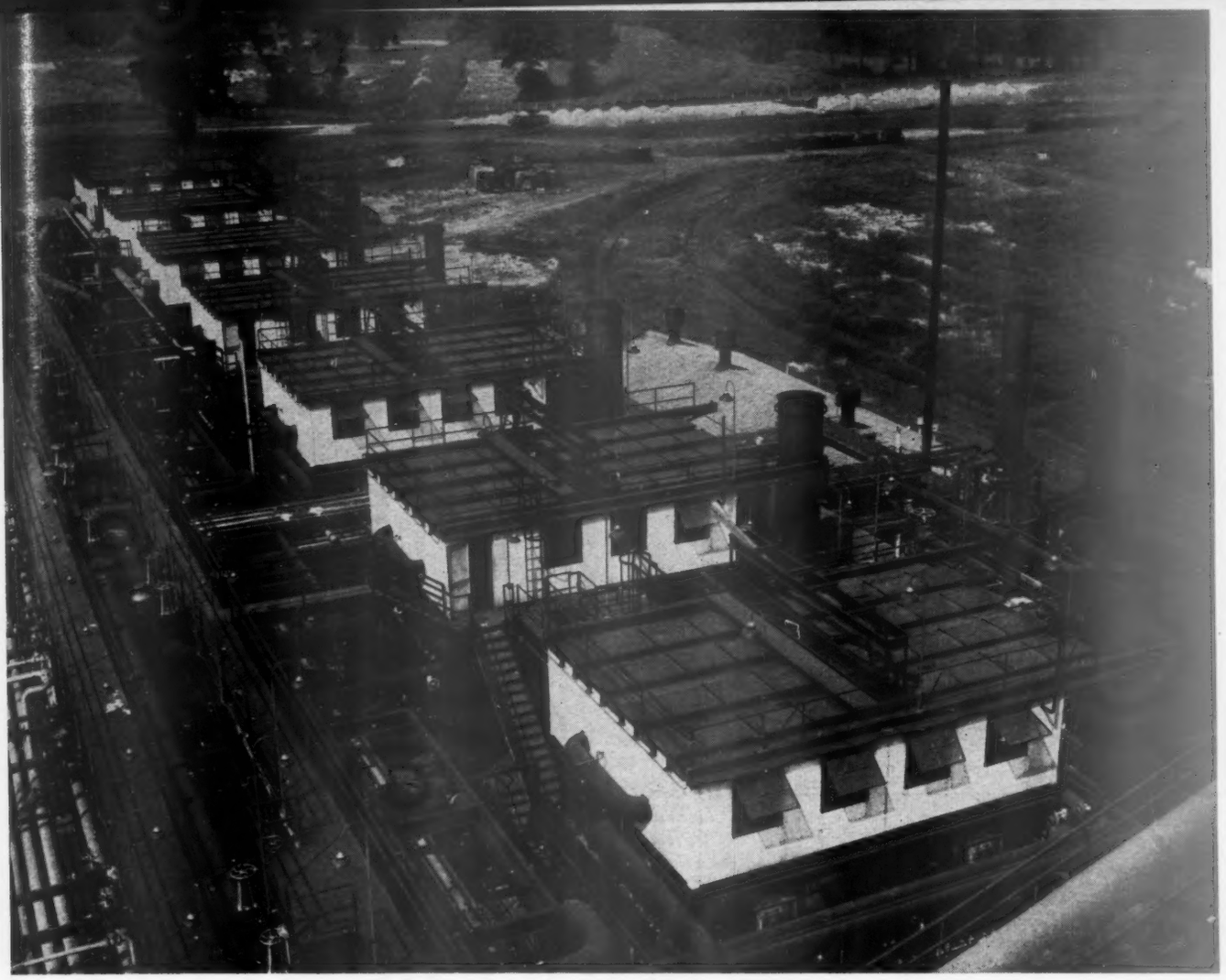


FIG. 2. Overhead view of ammonia synthesis gas primary reformers; methanol synthesis gas reformers.

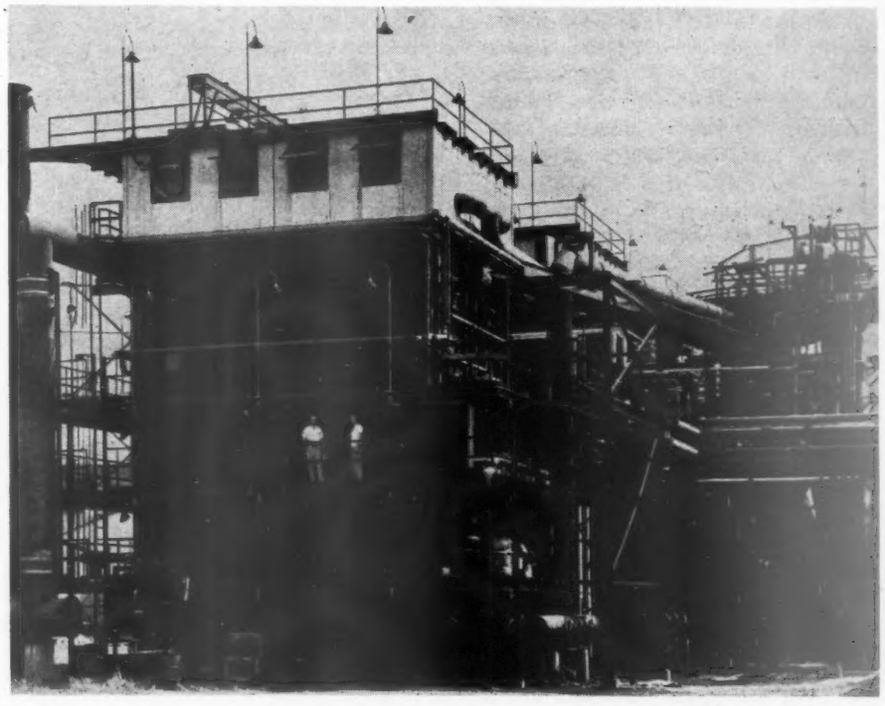
bon monoxide, argon, and methane as impurities, goes to a raw gas holder. Compression and final purification of the synthesis gas is carried out with the same equipment that was used when the synthesis gas was produced from coke.

At the South Point plant natural gas is also used for the production of methanol synthesis gas by reacting natural gas with steam and carbon dioxide in reformers similar to the primary reformers used to produce the hydrogen-rich gas in the ammonia synthesis gas plant. A portion of the carbon dioxide which is removed in purifying the ammonia synthesis gas is used for supplying the carbon dioxide required in making the methanol synthesis gas.

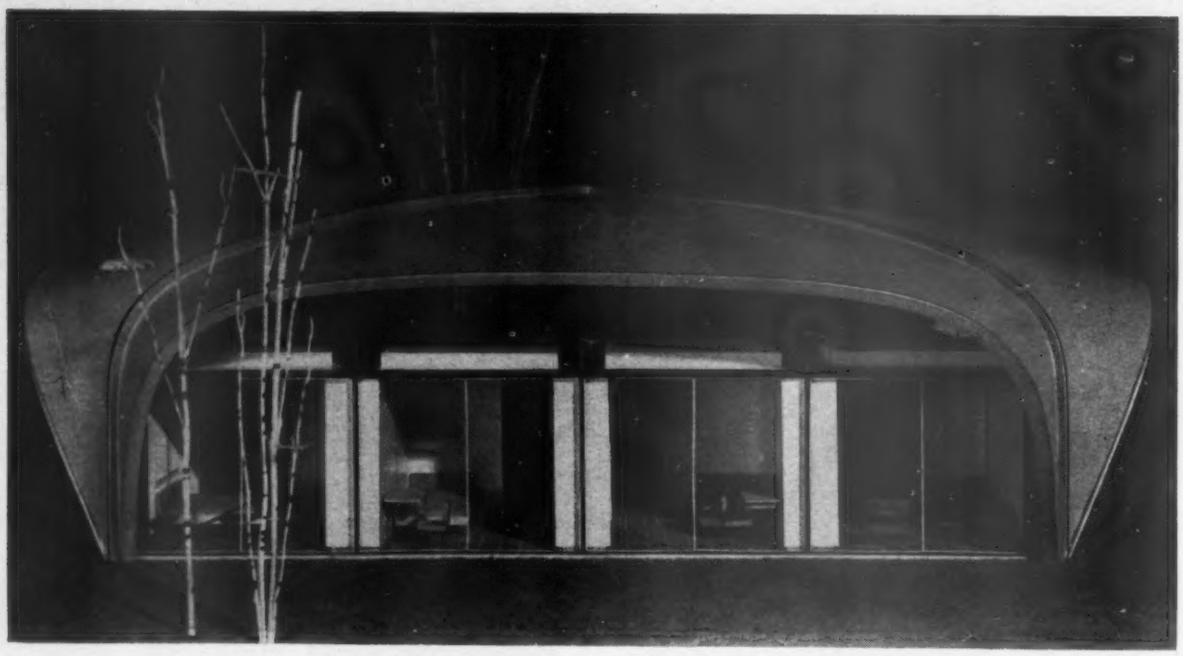
Fig. 2 shows the ammonia synthesis gas primary reformers and the methanol synthesis gas reformers. Fig. 3 is a side view of a methanol synthesis gas reformer. These reformers are the largest units of this type ever built.

The synthesis gas plants were designed, engineered, and constructed by The Girdler Company, Louisville, Kentucky, and the reforming catalyst was also supplied by Girdler. * * *

FIG. 3. Side view of a menthanol synthesis gas reformer, largest ever built of this type.



Part III



Dr. George Barsky
Barsky & Strauss, Inc.
New York City

Plastics in Preview

Some ideas of the future and their significance to the petroleum industry

One of the outstanding examples of plastics used in building is the General Electric Wonder Home, 1964, an architect's concept of the American home ten years from now. (See photo above)

The house is built almost entirely of prefabricated plastic panels. Roof is constructed of two sheets of plastics bonded together by foamed insulations. The panels have structural strength, serve as the thermal insulation and vapor seal, are acoustically treated and permanently finished.

Outside wall panels are made like the roof panels. Inside partitions are of decorative laminated plastic.

Floors are plastic panels into which ducts are built for air conditioning and cleaning system, the main wring circuits and the plastic piping. Floors use resins which give resilience and are water and chemical resistant.

Bathroom lavatories are molded into the plastic vanities. Master bathroom has plastic tub and shower stall.

Ceilings over bathrooms and bedroom hall and translucent plastic.

EXCLUSIVE

MAN'S imagination has always soared beyond his ability to bring his dreams to realization. The newer the realm of activity, the greater has been the time-gap between concept and accomplishment. Although the future for plastics has been highly romanticized, the technologist bases his predictions on definite and discernible trends and limits them to reasonable periods of time. There are four phases of the plastic industry that warrant discussion here: Use trends, new materials, raw material sources, and orientation of the industry toward petroleum.

Use Trends

It can be definitely stated that expansion at an ever increasing pace will take place in the use of plastic materials for established outlets, as improved materials become available to meet more exacting and more varied requirements. This is illustrated by recent improvements in high impact molding materials, such as the modified polystyrenes.

The same hastening trend in the new uses and in greater consumption will be fostered by new fabricating techniques. Particularly desirable and therefore undoubtedly to be developed in the near future are new methods for fabricating large pieces on a mass production scale.

Mechanical and chemical processing on previously formed pieces has received some attention as "post-forming," a technique devised to facilitate fabrication. This type of processing will become more prominent because it permits greater choice in methods of fabrication. Thus, by exposing some types of plastic to radiation, improved resistance to elevated temperatures and increased tensile strength are obtained.

In steel products there is a parallel post-forming operation known as heat-treatment.

Plastics are now being used in modern architecture. Laminates, translucent panels, and collapsible partitions will be more extensively employed for the "new look." Integral window and doorway jamb-wall sections are probable innovations, as they reduce labor requirements on the job and neither warp nor need painting like wood. For use on exterior walls, plastics have an advantage over metal in that they have lower heat conductivity and do not sweat. Molding a transparent window in one piece—to take the place of frame, pane and accompanying glazing—is a good possibility.

The plastic wall tile now used is patterned after conventional tile and does not take advantage of the innate characteristics of plastics. New variations from the conventional in ceramic tile and in linoleum wall covering are due in the near future. Flooring, too, is on the verge of marked changes to plastics. Conventional flooring, now built up on the job, will be displaced by factory-made composite panels. Some discussion of bathroom plumbing fixtures of plastic materials has appeared and innovations are expected.

An attractive outlet for plastics is the furniture field. Table tops, drawers, and chairs of plastic are widely available. The properties of wood and the limited methods employed in its fabrication, however, have so conventionalized the design of ordinary furniture that it is difficult for both the designer and the public to break away from traditional forms. To utilitize properly plastics, there is a crying need for changes in designs that will avoid the limitations set by entrenched ideas which originated with old materials. The plastic chairs that appeared a few years ago—although comfortable—presented a needlessly abrupt change and seemed quite absurd to the eye. On the other hand, the change in designs of radio cabinets from those of the 1920's was well accepted and exemplifies the transition from old designs to the new.

The poundage of plastics used in automobile for hardware, trim, small gears, etc., is increasing steadily. In the entire field of transportation the advantages of light weight and freedom from corrosion are attractive features. When only a relatively small number of units are required, as in the cases of special trucks and sport car bodies, metals do not have the great advantage of mass production techniques. For large pieces required in large numbers, plastics cannot at present compete with metals because they cannot be fabricated by the same low-cost techniques and designs evolved for mass-produced metal units. New fabricating techniques and new designs are required if net savings are to be made. In the case of passenger automobile bodies, designs that will minimize or perhaps eliminate upholstery, hardware, or other components, must be evolved. The manufacturers of gadgets and toys deserve much credit for the initiative and ingenuity they have displayed in adapting their designs to take advantage of the properties of plastics. What they have done on the small pieces points the way to what will follow on full scale pieces.

Future trends in uses and materials make petroleum the most promising source for synthetic structural materials.

Packaging, to a considerable extent, is in the throes of revolutionary changes due to plastics. The start was made by cellophane and great impetus was contributed by polyethylene which has usual adaptability to food wrapping that meshes so well with mass distribution of fresh and frozen foodstuffs. Paper laminated or impregnated with plastic is almost a new material. Polythylene containers, such as squeeze bottles, appeared only a few years ago. As polyethylene drops in price—and it undoubtedly will—it will be more widely used. Improved varieties of plastics, such as a transparent grade of polyethylene, will accelerate the consumption of plastics in packaging. Variations away from conventional design for glass bottles and jars are in the offing.

As the electrical industry and its various branches expand, they offer an ever-growing market for molding compounds and insulating materials. The large number of houses being built and their greater comfort and multiplied gadgets mean more wiring and more non-conductor parts. Both push-button civilization and its Nemesis, push-button warfare, involving as they do all sorts of electronic devices, are dependent on plastics—even for the buttons themselves.

New Materials

Almost all, if not all, of the currently available low cost low molecular weight units capable of reacting to form macromolecules have been investigated. Some are the bases of well known plastic materials. Therefore, it is not expected that any material entirely new chemically will be developed in the next 20 years or so. But the products from combinations of these units will be multiplied. The availability in the future of low cost monomeric units, for example, the di-isocyanates, will result in the commercial development of some materials now in the experimental stage. In addition, new techniques of manufacture, such as high pressure so successfully employed for producing polyethylene, will allow exploitation of reactions not now practicable. New products from acetylene and some of carbon monoxide will result from developments in high pressure technique.

Several of the recently announced materials are likely to grow in volume in the next two decades. The di-isocyanate combinations for foamed-in-place insulation and for high abrasion service are promising. Research underway on new textile fibers will result in some new plastics for nontextile uses. The application of new ideas of polymerization and copolymerization (such as "graft polymerization") of well known raw materials will provide a greater selection of property combinations than is available with present techniques. Alloys of plastic materials and composite structures of two or more materials are likely to attain greater prominence.

Raw Materials

As the plastics industry grows, supplies of raw material will become more and more important, and the suppliers more and more dominant, as is becoming the case with the chemical industry generally.

The three basic sources of organic raw materials will not change: Coal, petroleum, and agricultural products. At present, chemical materials from coal are by-products of the steel industry, whose growth is now much slower than that of the chemical industry. Attempts at greater direct chemical utilization of coal have not been on a sound economic basis. Low temperature carbonization was one try in this direction. The recently announced coal hydrogenation process of Carbide and Carbon Chemical Company is another. For these processes to be sound, they must have a very large outlet for non-chemical by-products; such an outlet can be only fuel. Because the cost of petroleum fuel is lower than that of coal, processes for chemicals from coal are under a handicap. Until the chemical industry develops outlets for some of the more complicated products of coal processing, there is little chance that the greater utilization of coal for chemical products will be successful.

Agricultural products as a raw material source for the chemical industry have been much discussed, but, except for a few products, very little headway has been made. However, with increased mechanization of agriculture, the cost of agricultural products rela-

tive to other raw materials should come down. Since agricultural crops are by-and-large expandable to meet demands, they have an advantage over fossil remains such as coal and oil, the total of which is fixed. Although exploration continually uncovers new sources, at some future date there will be no further unknown sources. Eventually agriculture will be our principal source of raw materials for the chemical industry.

Up to now, the use of agricultural products for plastic materials has been limited to small amounts of furfural, carbohydrates via fermentation, and vegetable oils. Transformation of these and other agricultural products to a greater variety of raw materials will not be technically and economically feasible in the immediate future. There are so many problems of economics, logistics, and technology that several decades will be required for their solution.

For the next 20 years, *only petroleum* can meet the demands of the expanding plastics industry for raw materials. Only petroleum has the advantage of a very large outlet for its main product, fuel. There are essentially no by-products, as whatever is not utilized as a chemical raw material can be diverted back to fuel. In other words, that part of petroleum that is diverted to chemical or plastics use is upgraded in value without any large sacrifice in the value of other products.

Orientation Toward Petroleum

In a previous article we mentioned the course followed in the relationship between manufacturers of plastic materials and of chemicals. These two groups are integrating their work. Plastic material manufacturers have gone into the production of their own raw materials, and chemical manufacturers have progressed to the manufacture of plastics from their materials.

In recent years, petroleum companies have taken an active interest in the chemical industry. Some have already invested large amounts of money in producing chemical products, such as ethanol and other alcohols, solvents, aromatics, ammonia, etc. At present they have extended the manufacture of chemical products beyond what might be called basic materials to products farther removed from petroleum and closer to the ultimate user. Examples of these are the production of phenol by the cumene process and the production of alkyl arylsulfonate detergents. Petroleum companies are looking more closely at the products, techniques, and marketing procedures of the chemical industry and chemical manufacturers are forming partnerships with petroleum companies.

Two changes that aroused the interest of the petroleum companies have taken place in the chemical industry over the last 20 years. One is the very rapid growth of the industry to a size that made it attractive for large investors; the other is the increasing dependence of the chemical industry on petroleum raw materials.

It is certain that an integrating process similar to that between the chemical and petroleum industries will be extended to the plastics industry. In some cases, the movement manifests itself by the organization of jointly owned subsidiaries between the chemical and petroleum companies; in others, by the organization in petroleum companies of wholly owned chemical departments or subsidiaries as in Shell Chemical, already the largest producer of epoxy resins.

The plastics industry, representing as it does a very large section of the chemical industry and being dependent to an increasing extent on petroleum for its raw materials, is an attractive field for expansion. The advent of polyethylene, almost a one step petroleum-to-plastic product, is a startling example of what can happen. Synthetic rubber, essentially a part of the plastics industry, derives its raw materials to a very large extent from petroleum and and owes some of its technological advance to the petroleum industry. The close connection between rubber and petroleum in automotive transportation is also a factor tending to knit synthetic rubber to petroleum.

Already the modern urge to diversity has drawn the petroleum and plastic industries close together. In coming years this trend will continue with even greater momentum because of the increasing competition and the need for greater production, and for more integration of raw material sources in the plastics industry and the incentive of greater margin of profits in the petroleum industry. * * *

The following acknowledgments are made to companies supplying photos for the series completed by this third part:

Part 1, May, 1955:
- Page C-37—Fig. 1—Dow Chemical Co.
- Page C-40—Fig. 2—Du Pont Co.
- Page C-40—Fig. 3—B. F. Goodrich Chemical Co.
- Page C-42—Fig. 5—B. F. Goodrich Chemical Co.

Part 2, June, 1955:
- Page C-49—Fig. 1—Watson Stillman Company.
- Page C-53—Fig. 2—U. S. Rubber Co.
- Page C-54—Fig. 3—B. F. Goodrich Chemical Co.
- Page C-55—Fig. 4—Du Pont Co.
- Page C-55—Fig. 5—Du Pont Co.

Part 3, August, 1955:
- Page C-10—Fig. 1.—General Electric Company.

Industrial Reodorants*

Working with specifically designed industrial reodorants it is possible to meet plant conditions and to treat various phases of plant operations to superimpose one odor on another and so essentially eliminate each. Reodorants are a specific class of chemicals and each problem must be studied individually to reach a solution.

For example, when asphalt manufacture is involved, vapors of generally acidic nature escape from the stacks; a specific reodorant can be steam-injected into the stack and thus eliminate the obnoxious odors, that have caused court suits, injunctions against plant operation, and other problems. In the regeneration of spent caustic in a light treater, reodorants can be steam-injected into the regenerator stacks to "kill" the odors of mercaptans, etc., that cause much public dissatisfaction. Acid sludges from lube oil treating units, when "cooked" to recover acid and condition the sludge for plant fuel, can and generally do, give off bad odors, usually hydrogen sulfide or similar compounds; this can be masked and the odors practically eliminated by use of the proper reodorant added directly to the sludge prior to cooking.

Operation of a Thermofor kiln, for regeneration of filter clays, catalysts, etc., produce obnoxious odors of oily hydrocarbon fumes, that can be masked by steam-injecting the proper reodorants directly into the stacks. Mixing and adding sulfurized mineral, vegetable and animal oils with hydrocarbon oils in making cutting oils generates seriously objectionable odors, when carried out at 300-350 F; addition of the proper materials to the mixture during especially the latter part of the cooking-mixing period has abated these difficulties.

Similarly, water from the barometric condenser of a vacuum distillation unit may carry bad odor frequently of sulfur origin, that is controlled by adding a reodorant directly to the water before injection into the condenser. One great source of bad odors that plague both the refinery area and surrounding territory is that of the collection of waste process waters from various refinery units, waters that are sent to the separators to recover oily matter and prevent its discharge into sewers, streams, etc. In handling this problem, a reodorant that is fitted to the specific problem is added to the waste water immediately after passing through the separators, and it acts by being volatilized along with the malodor to correct the bad smells that otherwise will pollute the atmosphere.

*(Footnote: Condensed from a paper by C. H. Nichols, Rhodia Inc., before Western Petroleum Refiners Association, May 27, 1955.)

EXCLUSIVE

Cobalt pipe to be used to test effect of gamma rays on chemicals and chemical reactions

Radioactivity Invades Oil Research Laboratory

A 2-IN. pipe of radioactive cobalt metal 13 in. long is stored safely in its special "dungeon" after bombardment for 2½ years in the atomic reactor at Brookhaven National Laboratories on Long Island, New York. It is owned by Esso Research and Engineering Company and is to be used to determine the effect of gamma rays on the reactions of hydrocarbons and in promoting the qualities of petroleum and petrochemical products. This tremendous piece of "pipe" has a radioactive strength of 3500 curies, as compared to the total *known* and *refined* quantity of radium, naturally radioactive element, of which an estimated 2400 curies are available in the entire world.

The interesting "little dungeon" consists of a lead cylinder weighing a mere three tons, 6000 lb, in which the cobalt pipe was transported via truck from the Brookhaven laboratory to Esso's Linden, New Jersey, location. This special laboratory is a 42 by 46 ft concrete house; the pipe is housed in a 6 by 9 ft "cave room" with 4-ft concrete walls for protection of the staff. When other materials are exposed to the rays from the pipe, they are affected chemically and physically but do not become radioactive. Thus staff members can handle oil samples exposed to the radiation with safety.

In using this piece of highly reactive cobalt inside a special room, mechanical "hands" will transport and move samples of oil, etc., and the pipe into the proper positions for a test. The reaction and the operations are observed through a block of lead-glass of 3-ft thickness to prevent injury to the observers. When not in use, the cobalt pipe is kept in a well 5 ft deep in the floor of the "cave room," in which, completely closed and capped, the rays are held entirely within the well. Thus operatives can enter the cave room to set up demonstrations and experiments manually before exposing the samples to the radioactivity of the pipe. Some samples may be placed within the interior of the pipe itself for extremely concentrated "treatments." After treatment, the samples may be analyzed in other nearby laboratories without danger of injury by radiation, these samples not becoming radioactive.

This Esso laboratory is the first and only private establishment in which this radioactive work can be carried on "dry;" other units in and out of the government find it necessary to carry on experiments under cover of water. Working in the absence of water avoids the problems of corrosion and also those of inconvenience in handling materials under water.

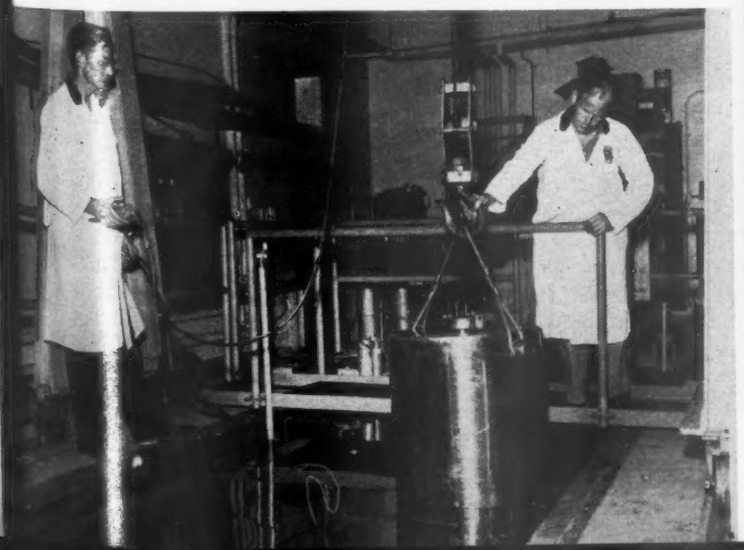
In addition to this highly specialized unit working with the very powerful radiation from this cobalt pipe, other units nearby are being set up for research on materials of low-strength radioactive isotopes, said to be "billions of times less reactive" than is the cobalt pipe unit. Those in charge of all this work, headed by E. V. Murphree, Esso research and engineering president, expect that hundreds of new applications of radioactivity to research and to processing will develop from all these investigations.

Tracing the flow of liquids, studying and measuring wear rate in automotive engines, and following chemical groups added to compounds chemically in organic research reactions are only a few of these possibilities, some of which are already in use in research organizations.

The accompanying photos give some idea of the conditions and the equipment employed in handling this highly radioactive cobalt pipe. * * *

◗ Dummy pipe is used here to illustrate manner of handling the highly radioactive 2-in. by 13-in. cobalt pipe to be used in research by Esso at Linden, New Jersey, laboratory.

◒ In this water-filled well, a 1½-ton lead container holds the radioactive pipe; this three-ton lead "pig" is lowered into the water, and the cobalt pipe is transferred into it from the smaller "pig," for transport to the Linden laboratory from Brookhaven.



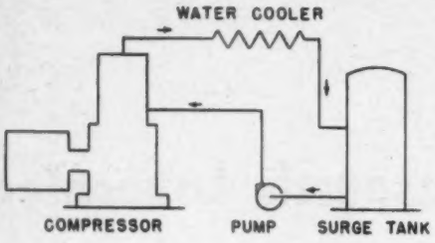


FIG. 1. Flow diagram of a conventional compressor cooling system.

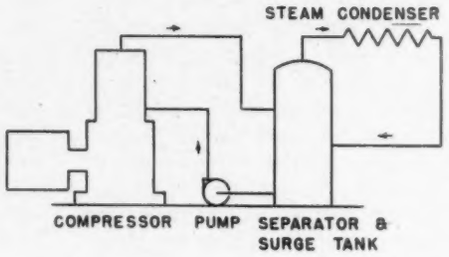


FIG. 2. Flow of coolant in a hot-water compressor cooling system.

Advantages of Latent Cooling of Compressors†

This unexploited system offers efficiencies over conventional methods by less corrosion, water condensation, etc.

H. MENARD and E. D. BLOSSOM

THE full potential of latent cooling of engine jackets with boiling water has not been utilized or developed. There are in use three general types of water cooling of engine jackets. The three types are conventional cooling, hot-water cooling, and latent cooling. After defining these types and comparing their operation, the advantages and potentials of the latent cooling system are apparent. Latent cooling is that method of cooling which transfers the engine heat to the water in the engine jacket by means of latent heat rather than sensible heat. This type of cooling has been variously referred to as vapor phase, boiling point, ebullition, evaporative, etc.

Conventional Cooling

The conventional cooling system shown in Fig. 1 utilizing sensible heat is found in the vast majority of water cooled engines. This system consists of a pump to circulate water through the engine, a water cooler for the removal of engine heat, and a surge tank for water capacity, and the removal of carbon dioxide and entrained gases.

This system is usually designed for a temperature rise of 10 F in the water pumped through the engine. A greater water circulation rate may reduce this temperature rise to 6 F. Some installations are operating with a temperature rise of 15 F. The water entering the engine may be at a temperature level as low as 125 F or as high as 180 F. This form of cooling will always find an application.

Hot-Water Cooling

The hot-water cooling system shown in Fig. 2 is quite similar to the conventional cooling method with one notable exception. The hot water from the engine is flashed in a steam separator. The steam is condensed and returned with the water from the separator to the pump. This system is usually designed for a 5 F temperature rise, but this rise might be as much as 10 F depending on the amount of water circulated. The water in the engine is near the boiling temperature, but the majority of the vaporization of the water occurs not in the engine, but in the separator with the release of pressure. Boiling does not occur in the engine because the pressure is maintained by the circulating pump. Although not widely used, the hot-water system has advantages.

Latent Cooling

Latent cooling is essentially different from the two methods described above. In the latent cooling system boiling actually occurs in the engine jacket. As shown in Fig. 3, this system does not necessarily include a pump as circulation may be obtained by thermosyphon. Steam is formed in the engine jacket and is displaced by water from the separating header. The separated steam is condensed and returned to the system with the displaced water. Because of a very low pressure drop in this system and the fact that the circulating water itself is not cooled, the water throughout the system is at the boiling temperature. If the condensate from the coils is subcooled a temperature rise may occur in the engine jacket. This is to be avoided. Practically a zero temperature rise in the jacket can be realized by proper design.

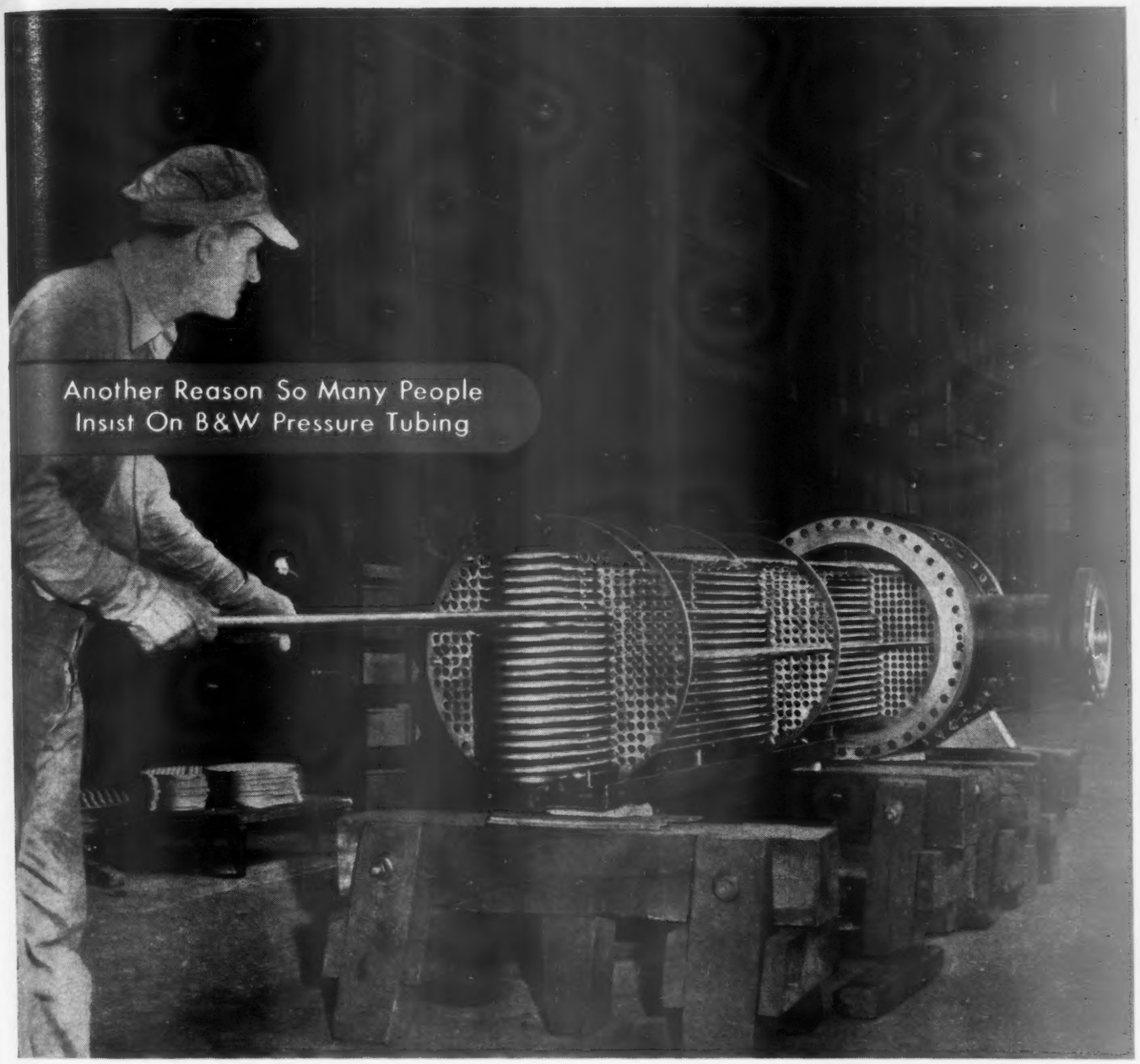
Latent cooling is not new. Among others the old Fairbanks Morse Type 2, single cylinder engine built in the early 1900's with an open cooling water jacket is a good example. As the water removed the cylinder heat by boiling, it was replaced by raw water make-up. The Bruce MacBeth engine is another example. Henry Ford's Model T utilized the latent cooling system, possibly unintentionally, when over-heated in warm weather.

In recent years latent cooling installations have been made by Tidewater Associated Oil Company on 4-cycle 300 hp compressors under the supervision of O. B. Freeman, who has done much toward developing field data. Installations have been made by five or six other companies in California with successful results.

Hot-Water Advantages

Hot-water cooling has advantages over conventional water cooling in that there is less temperature increase of the water passing through the jackets. The higher temperature level reduces the possibility of water condensation within the power cylinder. Because of less condensation there is less tendency for corrosion to occur. Initial costs are less because of the smaller cooling sur-

†Presented before Natural Gasoline Association of America.



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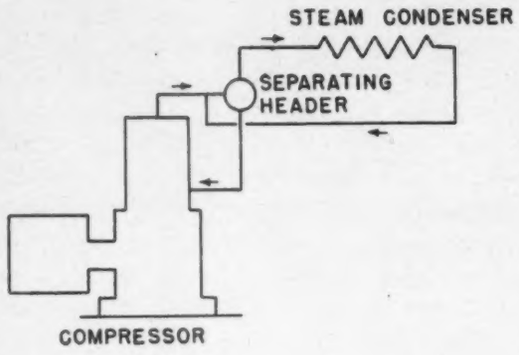


FIG. 3. Method for latent cooling of compressors, with steam production as an alternative possibility.

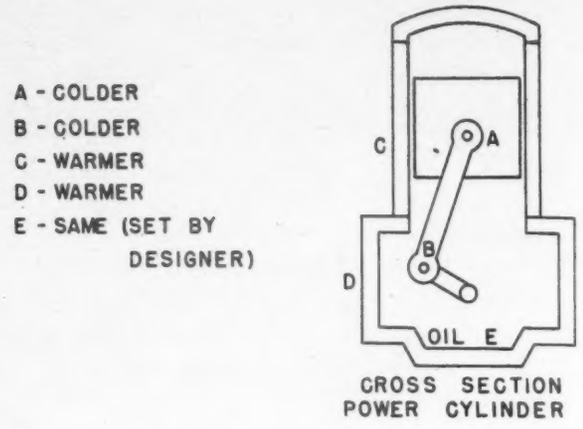


FIG. 4. Diagrammatic representation of heat distribution in a compressor power cylinder with latent cooling.

face required to condense the steam rather than cool the water.

Latent System Advantages

The latent cooling system compared to the conventional and hot-water systems has several distinct operating advantages as shown in Table 1. Latent cooling has little or no temperature rise of the water passing through the engine. In the first two systems cooling depends on turbulence. Even with the best water jacket design, cooling is not uniform and temperature rise is only an average.

In latent cooling the water is at the boiling temperature and all heat transfer occurs by boiling at that uniform temperature. Thermal expansion or distortion is thereby greatly reduced. With a decreased distortion the piston rings have a better chance of eliminating blow-by with a more perfect cylinder wall contact throughout the power stroke. Less blow-by produces less carbon and thus a longer engine life with less maintenance. With less blow-by the piston runs cooler. Rod and bearing temperatures are cooler, and less heat is rejected in the oil cooler.

The latent cooling system produces warmer outside cylinder temperatures, which are not objectionable. With less operating equipment, such as the water pump and water pump engine, fewer operating failures are to be expected.

The above statements were based, in part, on Signal Oil and Gas Company's installation at Huntington Beach, California. That installation consists of two 660 hp 2-cycle oil-cooled-piston compressors operating at 90 per cent rated load. One of the compressors was a new installation. The other was converted from the conventional type of cooling. The latter engine had operated with the conventional cooling for 9 months prior to converting to latent cooling. These 2 compressors are part of a group of the same model engines with the same compressor load. The other engines in the group are still cooled by the conventional system.

Because the very same engine has operated on both types of cooling, a good comparison between the two systems can be made. The engine was converted without a major overhaul. After start-up with latent cooling, under the same load as with conventional cooling, some changes were noted. The first change was a decrease in the engine exhaust temperatures. This drop in exhaust temperatures averaged 35 F.

The lubricating oil temperature was also found to drop when the engine was converted. The drop was sufficient to cause the oil temperature to go below the manufacturer's recommended minimum. In order to bring the temperature up, the cooling water going to the same lube oil cooler was reduced. That indicates a reduction in the heat rejected to the lube oil from the oil cooled power pistons.

After both engines were operated on latent cooling for a year they were shut down for inspection. The power cylinders showed no measurable wear. There was very little carbon in the intake and exhaust ports. Practically no carbon was found behind the piston rings. On the new engine all of the

TABLE 1. Comparison of Operation.

	Conventional cooling	Latent cooling
1. Temperature rise	6-15 deg	0-2 deg
2. Thermal expansion	Distortion	Less distortion
3. Piston blow-by	Normal	Less blow-by
4. Carbon behind rings and in ports	Normal	Less carbon
5. Piston temperature	Normal	Lower temperature
6. Outside cylinder surface temp.	Normal	Higher temperature
7. Rod and bearing temperature	Normal	Lower temperature
8. Oil temperature	Normal	Normal (maintained at manufacturer's recommended temp.)
9. Heat rejected in lube oil	Normal	Less heat (see discussion)
10. Power cylinder corrosion	Normal	Less corrosion (less condensing)
11. Failures causing shut-down	Fans, pump, make-up	Fans, make-up
12. Ring wear	Normal	Less wear
13. Power cylinder wear	Normal	Less wear
14. Carbon in ports	Normal	Less carbon

The Authors

Menard Blossom

Harvey Menard is the general superintendent of the gas department with the Signal Oil and Gas Company. He joined Signal Oil and Gas Company in 1947, as gas engineer. He was advanced to process engineer until 1951, at which time he was made general superintendent. Menard is a graduate of the University of Washington where he received a BS degree in chemical engineering in 1943. He was formerly employed as a process engineer with Bechtel McCone Parsons; sales engineer with Crosby Steam Gage and Valve; as a chemist with Ohio Oil Company, and as a fractional analyst and consultant in partnership with E. E. Shafer Laboratories, prior to his employment with Signal Oil and Gas Company.

Edson D. Blossom is the engineer in charge of equipment for Signal Oil and Gas Company. He is a graduate of the University of California with a BS degree in mechanical engineering. Blossom has been with Signal Oil and Gas Company since graduation in 1949.

rings except the two first power rings still showed most of the original manufacturer's tool marks on them.

The maintenance crew reports that the bearings operate cooler with latent cooling. When an engine with conventional cooling is first shut down the power rod bearings are too hot to handle with the bare hand. With latent cooling the bearings can be handled immediately with the bare hand. In both cases the crank case oil temperatures were maintained the same by controlling the amount of cooling water circulated through the oil cooler.

In order to explain why the heat rejected in the lube oil is less, observe Fig. 4. With latent cooling the piston is cooler. That is because of less blow-by in the power cylinder, better piston and ring lubrication, better heat transfer from the piston through the rings to the cylinder walls, and better heat transfer through the cylinder wall to the jacket water. Because the piston is cooler, less heat is passed down the piston rod to the rod bearings and the crank case. Note, however, the outside surface of the water jackets operates at a higher temperature with latent cooling.

The temperature difference between conventional cooled outside cylinder temperatures and latent cooled outside cylinder temperatures is only 30 or 40 F and is not noticeable, but it does mean that more heat is rejected down the frame to the crank case. The change in the crank case oil temperature with latent cooling depends on which quantity of heat changes the most; the increased heat flow down the frame, or the decreased heat flow through the piston and rod. In Signal Oil and Gas Company's operation (2 cycle engines with oil cooled pistons) the total heat rejected to the oil was found to be less.

Maintenance Costs

One particular increase in maintenance costs has been observed with latent cooling. The power sleeve, in the above mentioned installation, is sealed at the bottom from the jacket water by a rubber seal ring. These seal rings bake at the warmer water temperature and become brittle. Once the engine is shut down thermal changes cause cracks in the rubber and water leaks develop. Recent experimental seal rings have shown promise of satisfactory service. This problem is found only in engines that depend on a rubber seal.

In order to condense all of the steam that is generated some sub-cooling of the condensate usually results. If the subcooled condensate is returned to the steam and water line out of the engine the condensate will be reheated on its way to the separating header. See Fig. 3.

If more than one engine utilizes the same separating header adequate surge capacity must be provided. When one engine is started up or shut down, considerable variation of the water level in the separating header is noted. If one engine is shut down on a multi-engine system, the steam pockets in the jacket are filled with water from the separating header. Water thus used may lower the level in the separating header enough to actuate a low level shut-down switch thus shutting down the other engine or engines connected to the header, if the header has insufficient surge capacity.

Installation Costs

In a new installation of large compressors considerable saving in capital investment can be realized with a latent cooling system. Referring to Table 2, the condenser is considerably smaller with latent cooling than the conventional cooler, because of the higher heat transfer rate with a condensing surface. Because of the higher temperature level the temperature difference in the air condenser is greater, thus a smaller air circulating fan with less horsepower can be used.

No circulating pump or pump drive is required with latent cooling. The thermosyphon phenomena can provide all of the circulation. With latent cooling the piping requirements are apt to be much less. That is because of the ease of unitizing the engines, thus eliminating the need for long large header systems. The high temperature cut out and the low pressure alarms on the conventional system are replaced by safety valves and a low level shut-down on the latent cooling system. The large surge tank in the conventional system is replaced by a separating header or large outlet header for each engine.

TABLE 2. Comparison of factors influencing the costs.

	Conventional cooling	Latent cooling
1. Installation		
(a) Cooling surface	Normal	Less surface required (condensing, better heat transfer coefficient and higher MTD)
(b) Fan	Normal	Less capacity required
(c) Pump	Normal	None required
(d) Pump drive	Normal	None required
(e) Piping	Normal	Short piping required
(f) Lube oil cooling	Normal	Same or slightly less cooling required
(g) Compressor cyl. cooling	Normal	Same
(h) Controls	High temp. cut-out	Low level shut-down
(i) Surge tank	One to system	Separating header for each engine.
2. Operation		
(a) Pump drive fuel	Normal	None required
(b) Maintenance pump and drive	Normal	None required
(c) Fan drive fuel	Normal	Less fuel required (could be none with turbine)
(d) Water treating	Normal	Similar
(e) Steam available	None	Some available
(f) Maintenance head gaskets	Normal	On engines having rubber seal rings, some gasket replacement required.

The latent cooling system cannot provide cooling for the lube oil cooler or the compressor cylinders. They may be cooled in the same manner as with a conventional system. A small circulating water system will provide.

Operating Costs

With latent cooling the operating costs are lower than with conventional cooling. No fuel or maintenance is needed for a circulating water pump and pump drive. In the case of the condenser fan less air capacity is required, as noted previously. The fuel for the fan can be eliminated entirely by utilizing some of the energy in the steam generated in the jackets. The steam can operate a turbine to run the fan (this same fan can also cool the lube oil).

If a turbine is used, the pressure drop through the turbine must be provided by either elevating the turbine or pumping back the condensate.

The low pressure steam that is generated by the latent cooling system is available for use. In fact, in a number of cases the steam generated is used for heating oil. In general, a refinery or natural gasoline plant has no real need for low pressure steam. If high pressure steam could be made available in sufficient quantities, however, boilers could be eliminated. The next logical question is can high pressure steam be made available with latent cooling. Calculations indicate that this is possible.

The exhaust temperatures have been found to be lower with latent cooling than with conventional cooling, indicating that less heat is rejected in the exhaust gases. That amount of heat which no longer goes out the exhaust must now be dissipated at some other point in the engine. The heat rejected in the lube oil has been found to decrease slightly. The only other place for the engine heat to go is through the engine cylinder jacket into the water. Latent cooling must therefore increase the heat transfer rate through the cylinder into the jacket.

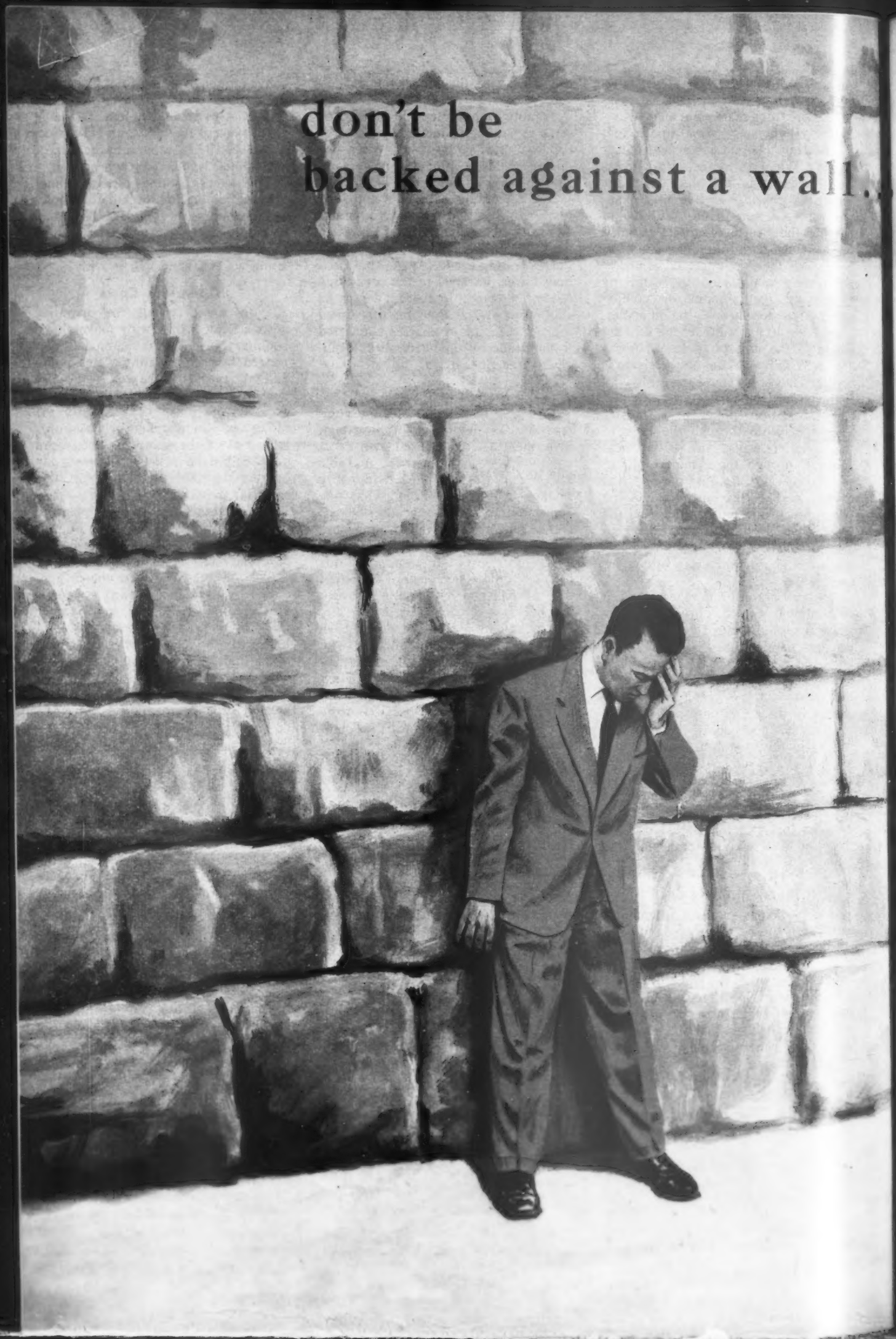
Granting the above statement, what does it mean regarding the generating of higher pressure steam?

If Q_c = Heat transferred with conventional system

Q_1 = Heat transferred with latent system

then $Q_1 = (X)(Q_c)$

where X = Ratio of heat transferred between the latent and conventional systems.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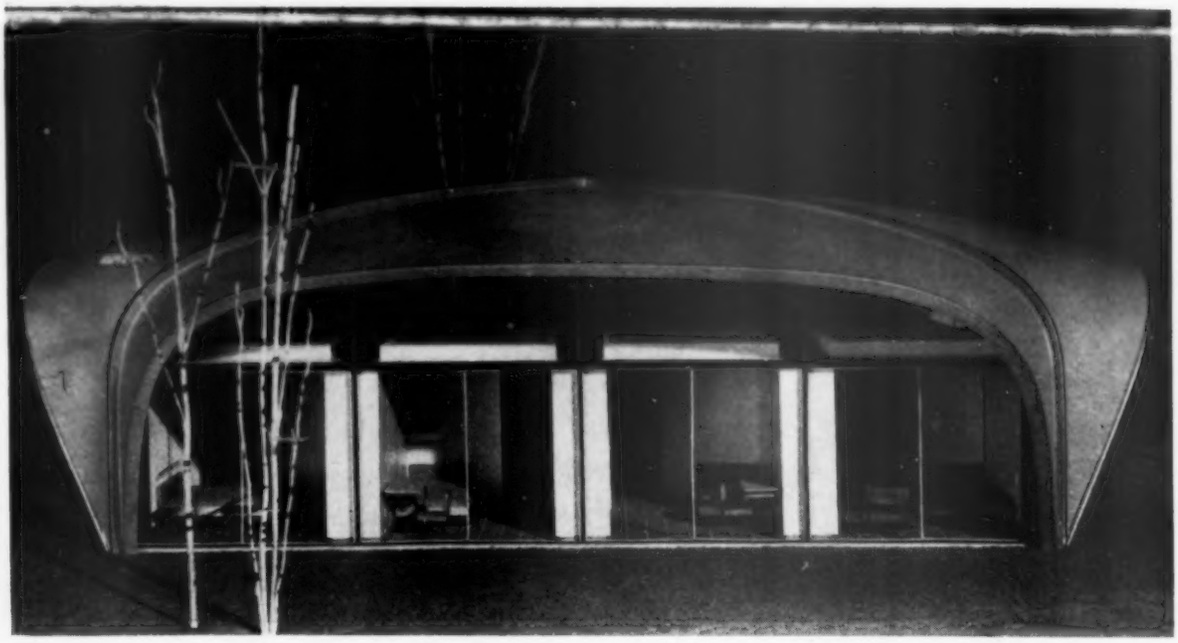


Dr. George Barsky
Barsky & Strauss, Inc.
New York City

Plastics in Preview

Some ideas of the future and their significance to the petroleum industry

One of the outstanding examples of plastics used in building is the General Electric Wonder Home, 1964, an architect's concept of the American home ten years from now. (See photo above)

The house is built almost entirely of prefabricated plastic panels. Roof is constructed of two sheets of plastics bonded together by foamed insulations. The panels have structural strength, serve as the thermal insulation and vapor seal, are acoustically treated and permanently finished.

Outside wall panels are made like the roof panels. Inside partitions are of decorative laminated plastic.

Floors are plastic panels into which ducts are built for air conditioning and cleaning system, the main wring circuits and the plastic piping. Floors use resins which give resilience and are water and chemical resistant.

Bathroom lavatories are molded into the plastic vanities. Master bathroom has plastic tub and shower stall.

Ceilings over bathrooms and bedroom hall and translucent plastic.

EXCLUSIVE

MAN'S imagination has always soared beyond his ability to bring his dreams to realization. The newer the realm of activity, the greater has been the time-gap between concept and accomplishment. Although the future for plastics has been highly romanticized, the technologist bases his predictions on definite and discernible trends and limits them to reasonable periods of time. There are four phases of the plastic industry that warrant discussion here: Use trends, new materials, raw material sources, and orientation of the industry toward petroleum.

Use Trends

It can be definitely stated that expansion at an ever increasing pace will take place in the use of plastic materials for established outlets, as improved materials become available to meet more exacting and more varied requirements. This is illustrated by recent improvements in high impact molding materials, such as the modified polystyrenes.

The same hastening trend in the new uses and in greater consumption will be fostered by new fabricating techniques. Particularly desirable and therefore undoubtedly to be developed in the near future are new methods for fabricating large pieces on a mass production scale.

Mechanical and chemical processing on previously formed pieces has received some attention as "post-forming," a technique devised to facilitate fabrication. This type of processing will become more prominent because it permits greater choice in methods of fabrication. Thus, by exposing some types of plastic to radiation, improved resistance to elevated temperatures and increased tensile strength are obtained.

In steel products there is a parallel post-forming operation known as heat-treatment.

Plastics are now being used in modern architecture. Laminates, translucent panels, and collapsible partitions will be more extensively employed for the "new look." Integral window and doorway jamb-wall sections are probable innovations, as they reduce labor requirements on the job and neither warp nor need painting like wood. For use on exterior walls, plastics have an advantage over metal in that they have lower heat conductivity and do not sweat. Molding a transparent window in one piece—to take the place of frame, pane and accompanying glazing—is a good possibility.

The plastic wall tile now used is patterned after conventional tile and does not take advantage of the innate characteristics of plastics. New variations from the conventional in ceramic tile and in linoleum wall covering are due in the near future. Flooring, too, is on the verge of marked changes to plastics. Conventional flooring, now built up on the job, will be displaced by factory-made composite panels. Some discussion of bathroom plumbing fixtures of plastic materials has appeared and innovations are expected.

An attractive outlet for plastics is the furniture field. Table tops, drawers, and chairs of plastic are widely avialable. The properties of wood and the limited methods employed in its fabrication, however, have so conventionalized the design of ordinary furniture that it is difficult for both the designer and the public to break away from traditional forms. To utilitize properly plastics, there is a crying need for changes in designs that will avoid the limitations set by entrenched ideas which originated with old materials. The plastic chairs that appeared a few years ago—although comfortable—presented a needlessly abrupt change and seemed quite absurd to the eye. On the other hand, the change in designs of radio cabinets from those of the 1920's was well accepted and exemplifies the transition from old designs to the new.

The poundage of plastics used in automobile for hardware, trim, small gears, etc., is increasing steadily. In the entire field of transportation the advantages of light weight and freedom from corrosion are attractive features. When only a relatively small number of units are required, as in the cases of special trucks and sport car bodies, metals do not have the great advantage of mass production techniques. For large pieces required in large numbers, plastics cannot at present compete with metals because they cannot be fabricated by the same low-cost techniques and designs evolved for mass-produced metal units. New fabricating techniques and new designs are required if net savings are to be made. In the case of passenger automobile bodies, designs that will minimize or perhaps eliminate upholstery, hardware, or other components, must be evolved. The manufacturers of gadgets and toys deserve much credit for the initiative and ingenuity they have displayed in adapting their designs to take advantage of the properties of plastics. What they have done on the small pieces points the way to what will follow on full scale pieces.

Future trends in uses and materials make petroleum the most promising source for synthetic structural materials.

Packaging, to a considerable extent, is in the throes of revolutionary changes due to plastics. The start was made by cellophane and great impetus was contributed by polyethylene which has usual adaptability to food wrapping that meshes so well with mass distribution of fresh and frozen foodstuffs. Paper laminated or impregnated with plastic is almost a new material. Polythylene containers, such as squeeze bottles, appeared only a few years ago. As polyethylene drops in price—and it undoubtedly will—it will be more widely used. Improved varieties of plastics, such as a transparent grade of polyethylene, will accelerate the consumption of plastics in packaging. Variations away from conventional design for glass bottles and jars are in the offing.

As the electrical industry and its various branches expand, they offer an ever-growing market for molding compounds and insulating materials. The large number of houses being built and their greater comfort and multiplied gadgets mean more wiring and more non-conductor parts. Both push-button civilization and its Nemesis, push-button warfare, involving as they do all sorts of electronic devices, are dependent on plastics—even for the buttons themselves.

New Materials

Almost all, if not all, of the currently available low cost low molecular weight units capable of reacting to form macromolecules have been investigated. Some are the bases of well known plastic materials. Therefore, it is not expected that any material entirely new chemically will be developed in the next 20 years or so. But the products from combinations of these units will be multiplied. The availability in the future of low cost monomeric units, for example, the di-isocyanates, will result in the commercial development of some materials now in the experimental stage. In addition, new techniques of manufacture, such as high pressure so successfully employed for producing polyethylene, will allow exploitation of reactions not now practicable. New products from acetylene and some of carbon monoxide will result from developments in high pressure technique.

Several of the recently announced materials are likely to grow in volume in the next two decades. The di-isocyanate combinations for foamed-in-place insulation and for high abrasion service are promising. Research underway on new textile fibers will result in some new plastics for nontextile uses. The application of new ideas of polymerization and copolymerization (such as "graft polymerization") of well known raw materials will provide a greater selection of property combinations than is available with present techniques. Alloys of plastic materials and composite structures of two or more materials are likely to attain greater prominence.

Raw Materials

As the plastics industry grows, supplies of raw material will become more and more important, and the suppliers more and more dominant, as is becoming the case with the chemical industry generally.

The three basic sources of organic raw materials will not change: Coal, petroleum, and agricultural products. At present, chemical materials from coal are by-products of the steel industry, whose growth is now much slower than that of the chemical industry. Attempts at greater direct chemical utilization of coal have not been on a sound economic basis. Low temperature carbonization was one try in this direction. The recently announced coal hydrogenation process of Carbide and Carbon Chemical Company is another. For these processes to be sound, they must have a very large outlet for non-chemical by-products; such an outlet can be only fuel. Because the cost of petroleum fuel is lower than that of coal, processes for chemicals from coal are under a handicap. Until the chemical industry develops outlets for some of the more complicated products of coal processing, there is little chance that the greater utilization of coal for chemical products will be successful.

Agricultural products as a raw material source for the chemical industry have been much discussed, but, except for a few products, very little headway has been made. However, with increased mechanization of agriculture, the cost of agricultural products rela-

XUM

tive to other raw materials should come down. Since agricultural crops are by-and-large expandable to meet demands, they have an advantage over fossil remains such as coal and oil, the total of which is fixed. Although exploration continually uncovers new sources, at some future date there will be no further unknown sources. Eventually agriculture will be our principal source of raw materials for the chemical industry.

Up to now, the use of agricultural products for plastic materials has been limited to small amounts of furfural, carbohydrates via fermentation, and vegetable oils. Transformation of these and other agricultural products to a greater variety of raw materials will not be technically and economically feasible in the immediate future. There are so many problems of economics, logistics, and technology that several decades will be required for their solution.

For the next 20 years, *only petroleum* can meet the demands of the expanding plastics industry for raw materials. Only petroleum has the advantage of a very large outlet for its main product, fuel. There are essentially no by-products, as whatever is not utilized as a chemical raw material can be diverted back to fuel. In other words, that part of petroleum that is diverted to chemical or plastics use is upgraded in value without any large sacrifice in the value of other products.

Orientation Toward Petroleum

In a previous article we mentioned the course followed in the relationship between manufacturers of plastic materials and of chemicals. These two groups are integrating their work. Plastic material manufacturers have gone into the production of their own raw materials, and chemical manufacturers have progressed to the manufacture of plastics from their materials.

In recent years, petroleum companies have taken an active interest in the chemical industry. Some have already invested large amounts of money in producing chemical products, such as ethanol and other alcohols, solvents, aromatics, ammonia, etc. At present they have extended the manufacture of chemical products beyond what might be called basic materials to products farther removed from petroleum and closer to the ultimate user. Examples of these are the production of phenol by the cumene process and the production of alkyl arylsulfonate detergents. Petroleum companies are looking more closely at the products, techniques, and marketing procedures of the chemical industry and chemical manufacturers are forming partnerships with petroleum companies.

Two changes that aroused the interest of the petroleum companies have taken place in the chemical industry over the last 20 years. One is the very rapid growth of the industry to a size that made it attractive for large investors; the other is the increasing dependence of the chemical industry on petroleum raw materials.

It is certain that an integrating process similar to that between the chemical and petroleum industries will be extended to the plastics industry. In some cases, the movement manifests itself by the organization of jointly owned subsidiaries between the chemical and petroleum companies; in others, by the organization in petroleum companies of wholly owned chemical departments or subsidiaries as in Shell Chemical, already the largest producer of epoxy resins.

The plastics industry, representing as it does a very large section of the chemical industry and being dependent to an increasing extent on petroleum for its raw materials, is an attractive field for expansion. The advent of polyethylene, almost a one step petroleum-to-plastic product, is a startling example of what can happen. Synthetic rubber, essentially a part of the plastics industry, derives its raw materials to a very large extent from petroleum and and owes some of its technological advance to the petroleum industry. The close connection between rubber and petroleum in automotive transportation is also a factor tending to knit synthetic rubber to petroleum.

Already the modern urge to diversity has drawn the petroleum and plastic industries close together. In coming years this trend will continue with even greater momentum because of the increasing competition and the need for greater production, and for more integration of raw material sources in the plastics industry and the incentive of greater margin of profits in the petroleum industry. * * *

The following acknowledgments are made to companies supplying photos for the series completed by this third part:

Part 1, May, 1955:
Page C-37—Fig. 1—Dow Chemical Co.
Page C-40—Fig. 2—Du Pont Co.
Page C-40—Fig. 3—B. F. Goodrich Chemical Co.
Page C-42—Fig. 5—B. F. Goodrich Chemical Co.

Part 2, June, 1955:
Page C-49—Fig. 1—Watson Stillman Company.
Page C-53—Fig. 2—U. S. Rubber Co.
Page C-54—Fig. 3—B. F. Goodrich Chemical Co.
Page C-55—Fig. 4—Du Pont Co.
Page C-55—Fig. 5—Du Pont Co.

Part 3, August, 1955:
Page C-10—Fig. 1.—General Electric Company.

Industrial Reodorants*

Working with specifically designed industrial reodorants it is possible to meet plant conditions and to treat various phases of plant operatiotns to superimpose one odor on another and so essentially eliminate each. Reodorants are a specific class of chemicals and each problem must be studied individually to reach a solution.

For example, when asphalt manufacture is involved, vapors of generally acidic nature escape from the stacks; a specific reodorant can be steam-injected into the stack and thus eliminate the obnoxious odors, that have caused court suits, injunctions against plant operation, and other problems. In the regeneration of spent caustic in a light treater, reodorants can be steam-injected into the regenerator stacks to "kill" the odors of mercaptans, etc., that cause much public dissatisfaction. Acid sludges from lube oil treating units, when "cooked" to recover acid and condition the sludge for plant fuel, can and generally do, give off bad odors, usually hydrogen sulfide or similar compounds; this can be masked and the odors practically eliminated by use of the proper reodorant added directly to the sludge prior to cooking.

Operation of a Thermofor kiln, for regeneration of filter clays, catalysts, etc., produce obnoxious odors of oily hydrocarbon fumes, that can be masked by steam-injecting the proper reodorants directly into the stacks. Mixing and adding sulfurized mineral, vegetable and animal oils with hydrocarbon oils in making cutting oils generates seriously objectionable odors, when carried out at 300-350 F; addition of the proper materials to the mixture during especially the latter part of the cooking-mixing period has abated these difficulties.

Similarly, water from the barometric condenser of a vacuum distillation unit may carry bad odor frequently of sulfur origin, that is controlled by adding a reodorant directly to the water before injection into the condenser. One great source of bad odors that plague both the refinery area and surrounding territory is that of the collection of waste process waters from various refinery units, waters that are sent to the separators to recover oily matter and prevent its discharge into sewers, streams, etc. In handling this problem, a reodorant that is fitted to the specific problem is added to the waste water immediately after passing through the separators, and it acts by being volatilized along with the malodor to correct the bad smells that otherwise will pollute the atmosphere.

*(Footnote: Condensed from a paper by C. H. Nichols, Rhodia Inc., before Western Petroleum Refiners Association, May 27, 1955.)

EXCLUSIVE

Cobalt pipe to be used to test effect of gamma rays on chemicals and chemical reactions

Radioactivity Invades Oil Research Laboratory

A 2-IN. pipe of radioactive cobalt metal 13 in. long is stored safely in its special "dungeon" after bombardment for 2½ years in the atomic reactor at Brookhaven National Laboratories on Long Island, New York. It is owned by Esso Research and Engineering Company and is to be used to determine the effect of gamma rays on the reactions of hydrocarbons and in promoting the qualities of petroleum and petrochemical products. This tremendous piece of "pipe" has a radioactive strength of 3500 curies, as compared to the total *known* and *refined* quantity of radium, naturally radioactive element, of which an estimated 2400 curies are available in the entire world.

The interesting "little dungeon" consists of a lead cylinder weighing a mere three tons, 6000 lb, in which the cobalt pipe was transported via truck from the Brookhaven laboratory to Esso's Linden, New Jersey, location. This special laboratory is a 42 by 46 ft concrete house; the pipe is housed in a 6 by 9 ft "cave room" with 4-ft concrete walls for protection of the staff. When other materials are exposed to the rays from the pipe, they are affected chemically and physically but do not become radioactive. Thus staff members can handle oil samples exposed to the radiation with safety.

In using this piece of highly reactive cobalt inside a special room, mechanical "hands" will transport and move samples of oil, etc., and the pipe into the proper positions for a test. The reaction and the operations are observed through a block of lead-glass of 3-ft thickness to prevent injury to the observers. When not in use, the cobalt pipe is kept in a well 5 ft deep in the floor of the "cave room," in which, completely closed and capped, the rays are held entirely within the well. Thus operatives can enter the cave room to set up demonstrations and experiments manually before exposing the samples to the radioactivity of the pipe. Some samples may be placed within the interior of the pipe itself for extremely concentrated "treatments." After treatment, the samples may be analyzed in other nearby laboratories without danger of injury by radiation, these samples not becoming radioactive.

This Esso laboratory is the first and only private establishment in which this radioactive work can be carried on "dry;" other units in and out of the government find it necessary to carry on experiments under cover of water. Working in the absence of water avoids the problems of corrosion and also those of inconvenience in handling materials under water.

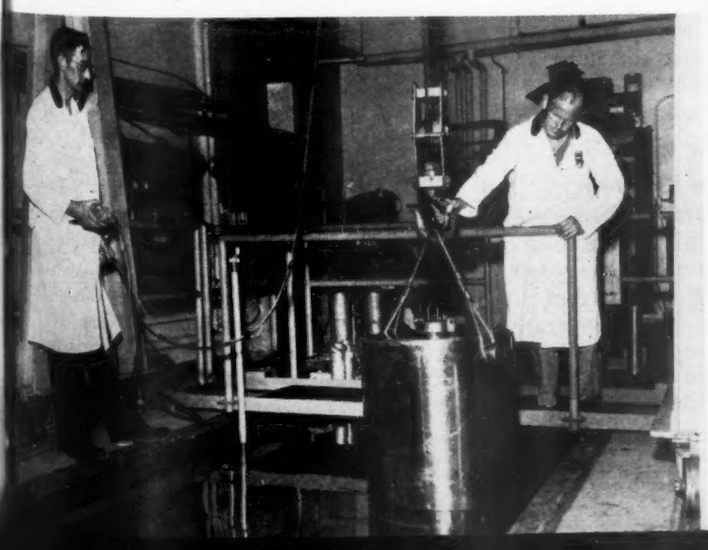
In addition to this highly specialized unit working with the very powerful radiation from this cobalt pipe, other units nearby are being set up for research on materials of low-strength radioactive isotopes, said to be "billions of times less reactive" than is the cobalt pipe unit. Those in charge of all this work, headed by E. V. Murphree, Esso research and engineering president. expect that hundreds of new applications of radioactivity to research and to processing will develop from all these investigations.

Tracing the flow of liquids, studying and measuring wear rate in automotive engines, and following chemical groups added to compounds chemically in organic research reactions are only a few of these possibilities, some of which are already in use in research organizations.

The accompanying photos give some idea of the conditions and the equipment employed in handling this highly radioactive cobalt pipe. * * *

◗ Dummy pipe is used here to illustrate manner of handling the highly radioactive 2-in. by 13-in. cobalt pipe to be used in research by Esso at Linden, New Jersey, laboratory.

◗ In this water-filled well, a 1½-ton lead container holds the radioactive pipe; this three-ton lead "pig" is lowered into the water, and the cobalt pipe is transferred into it from the smaller "pig," for transport to the Linden laboratory from Brookhaven.



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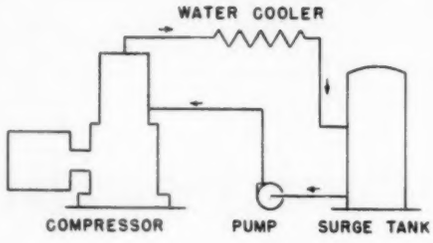


FIG. 1. Flow diagram of a conventional compressor cooling system.

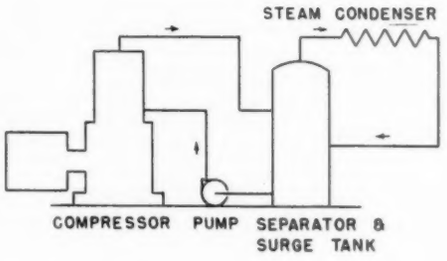


FIG. 2. Flow of coolant in a hot-water compressor cooling system.

Advantages of Latent Cooling of Compressors†

This unexploited system offers efficiencies over conventional methods by less corrosion, water condensation, etc.

H. MENARD and E. D. BLOSSOM

THE full potential of latent cooling of engine jackets with boiling water has not been utilized or developed. There are in use three general types of water cooling of engine jackets. The three types are conventional cooling, hot-water cooling, and latent cooling. After defining these types and comparing their operation, the advantages and potentials of the latent cooling system are apparent. Latent cooling is that method of cooling which transfers the engine heat to the water in the engine jacket by means of latent heat rather than sensible heat. This type of cooling has been variously referred to as vapor phase, boiling point, ebullition, evaporative, etc.

Conventional Cooling

The conventional cooling system shown in Fig. 1 utilizing sensible heat is found in the vast majority of water cooled engines. This system consists of a pump to circulate water through the engine, a water cooler for the removal of engine heat, and a surge tank for water capacity, and the removal of carbon dioxide and entrained gases.

This system is usually designed for a temperature rise of 10 F in the water pumped through the engine. A greater water circulation rate may reduce this temperature rise to 6 F. Some installations are operating with a temperature rise of 15 F. The water entering the engine may be at a temperature level as low as 125 F or as high as 180 F. This form of cooling will always find an application.

Hot-Water Cooling

The hot-water cooling system shown in Fig. 2 is quite similar to the conventional cooling method with one notable exception. The hot water from the engine is flashed in a steam separator. The steam is condensed and returned with the water from the separator to the pump. This system is usually designed for a 5 F temperature rise, but this rise might be as much as 10 F depending on the amount of water circulated. The water in the engine is near the boiling temperature, but the majority of the vaporization of the water occurs not in the engine, but in the separator with the release of pressure. Boiling does not occur in the engine because the pressure is maintained by the circulating pump. Although not widely used, the hot-water system has advantages.

Latent Cooling

Latent cooling is essentially different from the two methods described above. In the latent cooling system boiling actually occurs in the engine jacket. As shown in Fig. 3, this system does not necessarily include a pump as circulation may be obtained by thermosyphon. Steam is formed in the engine jacket and is displaced by water from the separating header. The separated steam is condensed and returned to the system with the displaced water. Because of a very low pressure drop in this system and the fact that the circulating water itself is not cooled, the water throughout the system is at the boiling temperature. If the condensate from the coils is subcooled a temperature rise may occur in the engine jacket. This is to be avoided. Practically a zero temperature rise in the jacket can be realized by proper design.

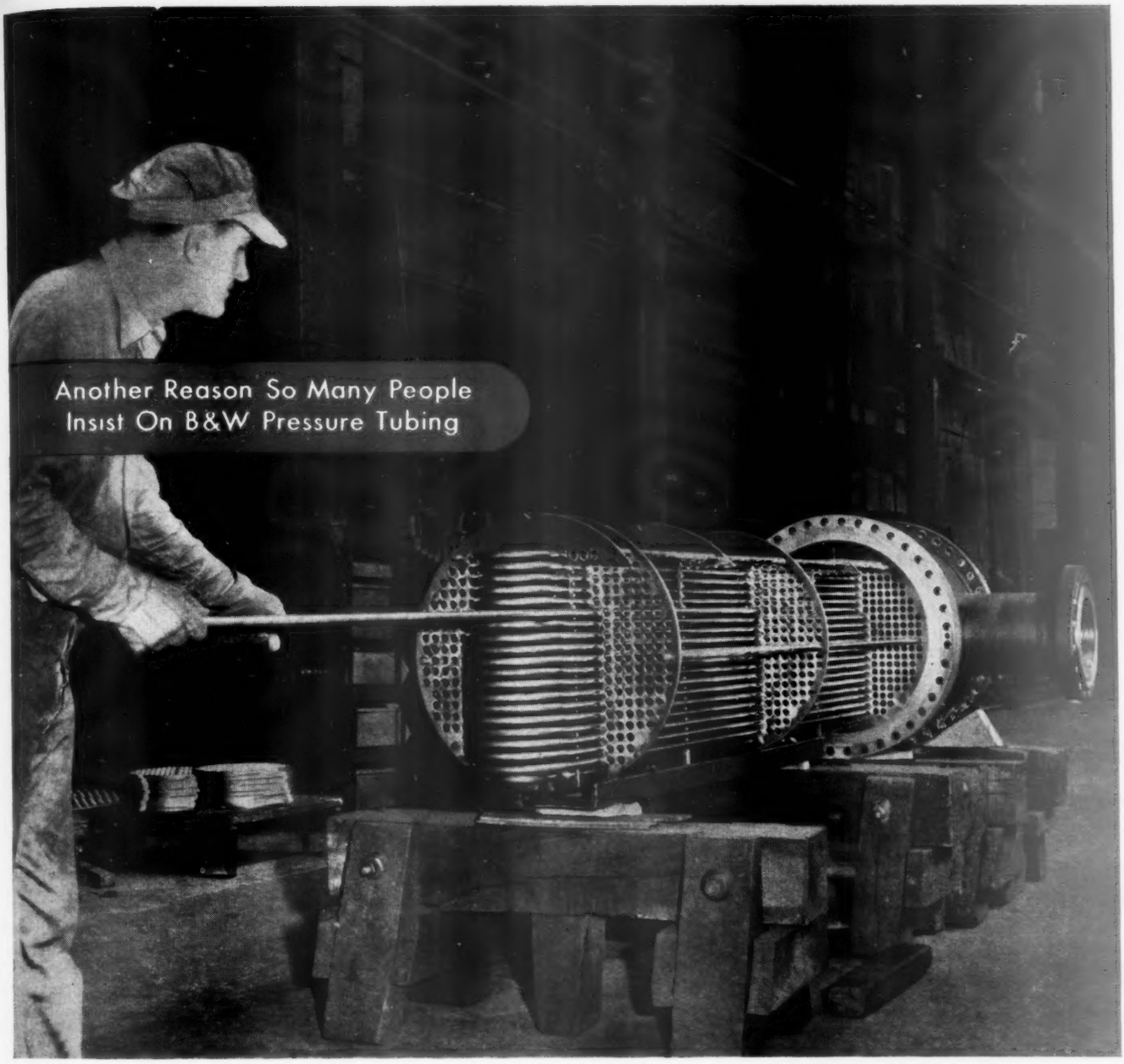
Latent cooling is not new. Among others the old Fairbanks Morse Type 2, single cylinder engine built in the early 1900's with an open cooling water jacket is a good example. As the water removed the cylinder heat by boiling, it was replaced by raw water make-up. The Bruce MacBeth engine is another example. Henry Ford's Model T utilized the latent cooling system, possibly unintentionally, when over-heated in warm weather.

In recent years latent cooling installations have been made by Tidewater Associated Oil Company on 4-cycle 300 hp compressors under the supervision of O. B. Freeman, who has done much toward developing field data. Installations have been made by five or six other companies in California with successful results.

Hot-Water Advantages

Hot-water cooling has advantages over conventional water cooling in that there is less temperature increase of the water passing through the jackets. The higher temperature level reduces the possibility of water condensation within the power cylinder. Because of less condensation there is less tendency for corrosion to occur. Initial costs are less because of the smaller cooling sur-

†Presented before Natural Gasoline Association of America.



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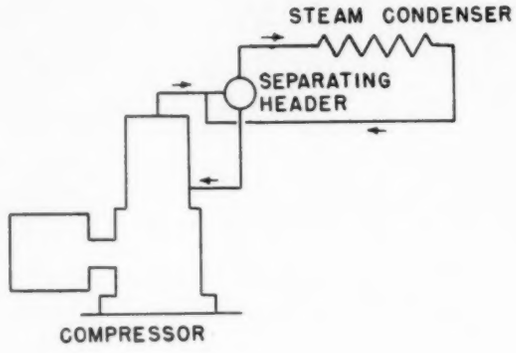


FIG. 3. Method for latent cooling of compressors, with steam production as an alternative possibility.

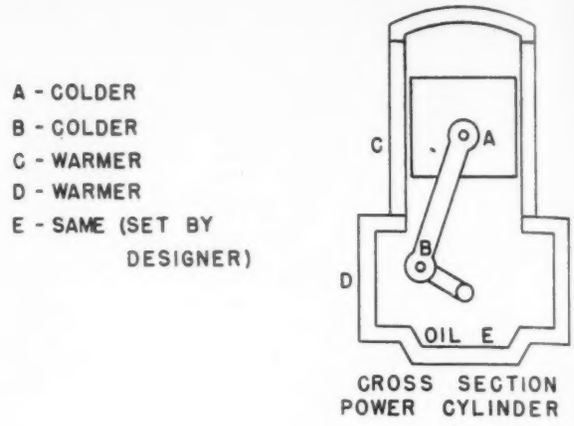


FIG. 4. Diagrammatic representation of heat distribution in a compressor power cylinder with latent cooling.

face required to condense the steam rather than cool the water.

Latent System Advantages

The latent cooling system compared to the conventional and hot-water systems has several distinct operating advantages as shown in Table 1. Latent cooling has little or no temperature rise of the water passing through the engine. In the first two systems cooling depends on turbulence. Even with the best water jacket design, cooling is not uniform and temperature rise is only an average.

In latent cooling the water is at the boiling temperature and all heat transfer occurs by boiling at that uniform temperature. Thermal expansion or distortion is thereby greatly reduced. With a decreased distortion the piston rings have a better chance of eliminating blow-by with a more perfect cylinder wall contact throughout the power stroke. Less blow-by produces less carbon and thus a longer engine life with less maintenance. With less blow-by the piston runs cooler. Rod and bearing temperatures are cooler, and less heat is rejected in the oil cooler.

The latent cooling system produces warmer outside cylinder temperatures, which are not objectionable. With less operating equipment, such as the water pump and water pump engine, fewer operating failures are to be expected.

The above statements were based, in part, on Signal Oil and Gas Company's installation at Huntington Beach, California. That installation consists of two 660 hp 2-cycle oil-cooled-piston compressors operating at 90 per cent rated load. One of the compressors was a new installation. The other was converted from the conventional type of cooling. The latter engine had operated with the conventional cooling for 9 months prior to converting to latent cooling. These 2 compressors are part of a group of the same model engines with the same compressor load. The other engines in the group are still cooled by the conventional system.

Because the very same engine has operated on both types of cooling, a good comparison between the two systems can be made. The engine was converted without a major overhaul. After start-up with latent cooling, under the same load as with conventional cooling, some changes were noted. The first change was a decrease in the engine exhaust temperatures. This drop in exhaust temperatures averaged 35 F.

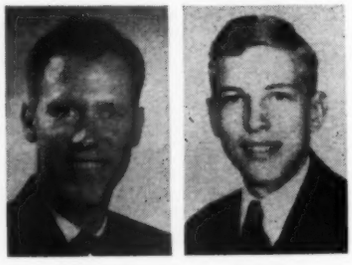
The lubricating oil temperature was also found to drop when the engine was converted. The drop was sufficient to cause the oil temperature to go below the manufacturer's recommended minimum. In order to bring the temperature up, the cooling water going to the same lube oil cooler was reduced. That indicates a reduction in the heat rejected to the lube oil from the oil cooled power pistons.

After both engines were operated on latent cooling for a year they were shut down for inspection. The power cylinders showed no measurable wear. There was very little carbon in the intake and exhaust ports. Practically no carbon was found behind the piston rings. On the new engine all of the

TABLE 1. Comparison of Operation.

	Conventional cooling	Latent cooling
1. Temperature rise	6-15 deg	0-2 deg
2. Thermal expansion	Distortion	Less distortion
3. Piston blow-by	Normal	Less blow-by
4. Carbon behind rings and in ports	Normal	Less carbon
5. Piston temperature	Normal	Lower temperature
6. Outside cylinder surface temp.	Normal	Higher temperature
7. Rod and bearing temperature	Normal	Lower temperature
8. Oil temperature	Normal	Normal (maintained at manufacturer's recommended temp.)
9. Heat rejected in lube oil	Normal	Less heat (see discussion)
10. Power cylinder corrosion	Normal	Less corrosion (less condensing)
11. Failures causing shut-down	Fans, pump, make-up	Fans, make-up
12. Ring wear	Normal	Less wear
13. Power cylinder wear	Normal	Less wear
14. Carbon in ports	Normal	Less carbon

The Authors



Menard Blossom

Harvey Menard is the general superintendent of the gas department with the Signal Oil and Gas Company. He joined Signal Oil and Gas Company in 1947, as gas engineer. He was advanced to process engineer until 1951, at which time he was made general superintendent. Menard is a graduate of the University of Washington where he received a BS degree in chemical engineering in 1943. He was formerly employed as a process engineer with Bechtel McCone Parsons; sales engineer with Crosby Steam Gage and Valve; as a chemist with Ohio Oil Company, and as a fractional analyst and consultant in partnership with E. E. Shafer Laboratories, prior to his employment with Signal Oil and Gas Company.

Edson D. Blossom is the engineer in charge of equipment for Signal Oil and Gas Company. He is a graduate of the University of California with a BS degree in mechanical engineering. Blossom has been with Signal Oil and Gas Company since graduation in 1949.

rings except the two first power rings still showed most of the original manufacturer's tool marks on them.

The maintenance crew reports that the bearings operate cooler with latent cooling. When an engine with conventional cooling is first shut down the power rod bearings are too hot to handle with the bare hand. With latent cooling the bearings can be handled immediately with the bare hand. In both cases the crank case oil temperatures were maintained the same by controlling the amount of cooling water circulated through the oil cooler.

In order to explain why the heat rejected in the lube oil is less, observe Fig. 4. With latent cooling the piston is cooler. That is because of less blow-by in the power cylinder, better piston and ring lubrication, better heat transfer from the piston through the rings to the cylinder walls, and better heat transfer through the cylinder wall to the jacket water. Because the piston is cooler, less heat is passed down the piston rod to the rod bearings and the crank case. Note, however, the outside surface of the water jackets operates at a higher temperature with latent cooling.

The temperature difference between conventional cooled outside cylinder temperatures and latent cooled outside cylinder temperatures is only 30 or 40 F and is not noticeable, but it does mean that more heat is rejected down the frame to the crank case. The change in the crank case oil temperature with latent cooling depends on which quantity of heat changes the most; the increased heat flow down the frame, or the decreased heat flow through the piston and rod. In Signal Oil and Gas Company's operation (2 cycle engines with oil cooled pistons) the total heat rejected to the oil was found to be less.

Maintenance Costs

One particular increase in maintenance costs has been observed with latent cooling. The power sleeve, in the above mentioned installation, is sealed at the bottom from the jacket water by a rubber seal ring. These seal rings bake at the warmer water temperature and become brittle. Once the engine is shut down thermal changes cause cracks in the rubber and water leaks develop. Recent experimental seal rings have shown promise of satisfactory service. This problem is found only in engines that depend on a rubber seal.

In order to condense all of the steam that is generated some sub-cooling of the condensate usually results. If the subcooled condensate is returned to the steam and water line out of the engine the condensate will be reheated on its way to the separating header. See Fig. 3.

If more than one engine utilizes the same separating header adequate surge capacity must be provided. When one engine is started up or shut down, considerable variation of the water level in the separating header is noted. If one engine is shut down on a multi-engine system, the steam pockets in the jacket are filled with water from the separating header. Water thus used may lower the level in the separating header enough to actuate a low level shut-down switch thus shutting down the other engine or engines connected to the header, if the header has insufficient surge capacity.

Installation Costs

In a new installation of large compressors considerable saving in capital investment can be realized with a latent cooling system. Referring to Table 2, the condenser is considerably smaller with latent cooling than the conventional cooler, because of the higher heat transfer rate with a condensing surface. Because of the higher temperature level the temperature difference in the air condenser is greater, thus a smaller air circulating fan with less horsepower can be used.

No circulating pump or pump drive is required with latent cooling. The thermosyphon phenomena can provide all of the circulation. With latent cooling the piping requirements are apt to be much less. That is because of the ease of unitizing the engines, thus eliminating the need for long large header systems. The high temperature cut out and the low pressure alarms on the conventional system are replaced by safety valves and a low level shut-down on the latent cooling system. The large surge tank in the conventional system is replaced by a separating header or large outlet header for each engine.

TABLE 2. Comparison of factors influencing the costs.

	Conventional cooling	Latent cooling
1. Installation		
(a) Cooling surface	Normal	Less surface required (condensing, better heat transfer coefficient and higher MTD)
(b) Fan	Normal	Less capacity required
(c) Pump	Normal	None required
(d) Pump drive	Normal	None required
(e) Piping	Normal	Short piping required
(f) Lube oil cooling	Normal	Same or slightly less cooling required
(g) Compressor cyl. cooling	Normal	Same
(h) Controls	High temp. cut-out	Low level shut-down
(i) Surge tank	One to system	Separating header for each engine.
2. Operation		
(a) Pump drive fuel	Normal	None required
(b) Maintenance pump and drive	Normal	None required
(c) Fan drive fuel	Normal	Less fuel required (could be none with turbine)
(d) Water treating	Normal	Similar
(e) Steam available	None	Some available
(f) Maintenance head gaskets	Normal	On engines having rubber seal rings, some gasket replacement required.

The latent cooling system cannot provide cooling for the lube oil cooler or the compressor cylinders. They may be cooled in the same manner as with a conventional system. A small circulating water system will provide.

Operating Costs

With latent cooling the operating costs are lower than with conventional cooling. No fuel or maintenance is needed for a circulating water pump and pump drive. In the case of the condenser fan less air capacity is required, as noted previously. The fuel for the fan can be eliminated entirely by utilizing some of the energy in the steam generated in the jackets. The steam can operate a turbine to run the fan (this same fan can also cool the lube oil).

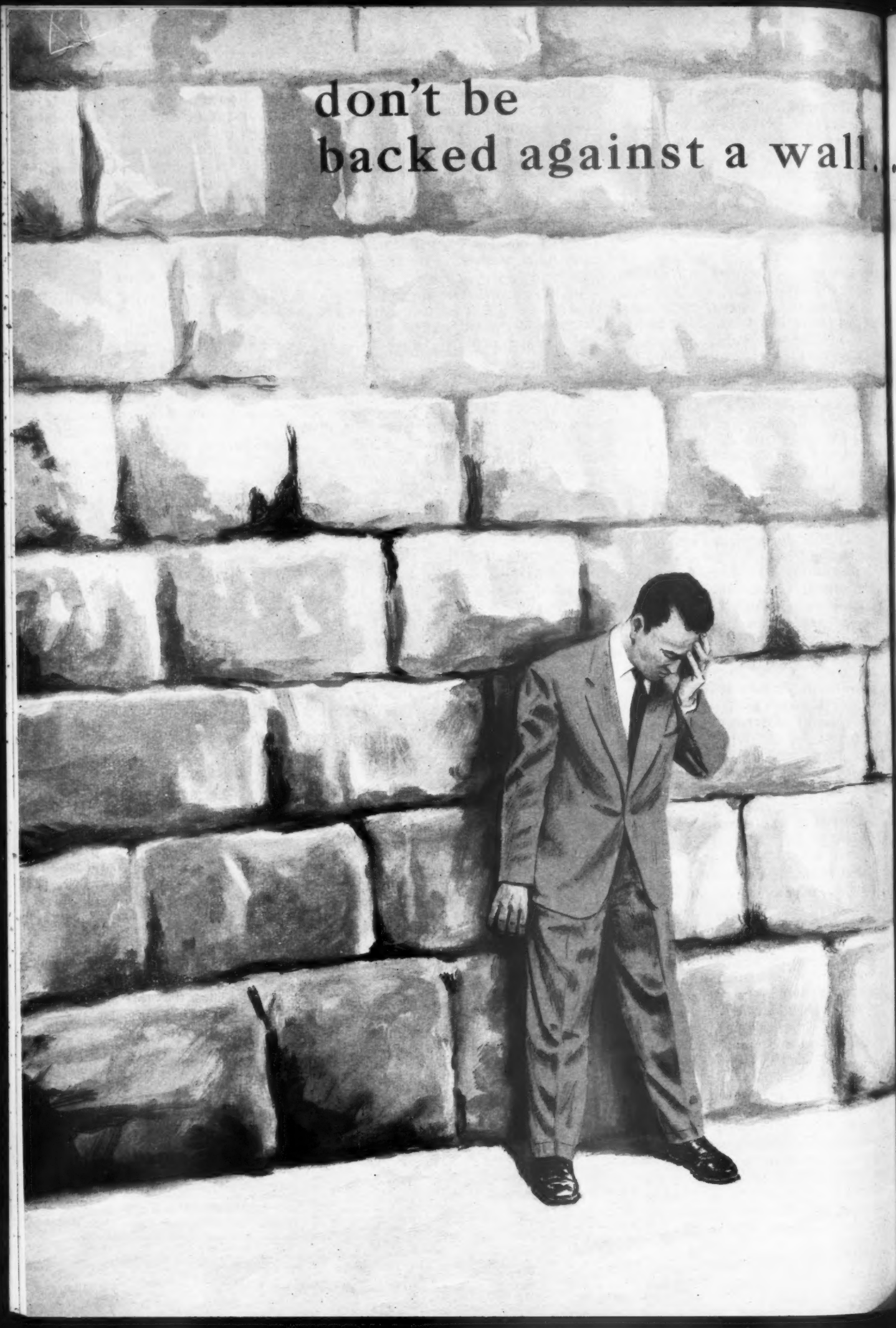
If a turbine is used, the pressure drop through the turbine must be provided by either elevating the turbine or pumping back the condensate.

The low pressure steam that is generated by the latent cooling system is available for use. In fact, in a number of cases the steam generated is used for heating oil. In general, a refinery or natural gasoline plant has no real need for low pressure steam. If high pressure steam could be made available in sufficient quantities, however, boilers could be eliminated. The next logical question is can high pressure steam be made available with latent cooling. Calculations indicate that this is possible.

The exhaust temperatures have been found to be lower with latent cooling than with conventional cooling, indicating that less heat is rejected in the exhaust gases. That amount of heat which no longer goes out the exhaust must now be dissipated at some other point in the engine. The heat rejected in the lube oil has been found to decrease slightly. The only other place for the engine heat to go is through the engine cylinder jacket into the water. Latent cooling must therefore increase the heat transfer rate through the cylinder into the jacket.

Granting the above statement, what does it mean regarding the generating of higher pressure steam?

If Q_c = Heat transferred with conventional system
Q_1 = Heat transferred with latent system
then $Q_1 = (X)(Q_c)$
where X = Ratio of heat transferred between the latent and conventional systems.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Assume X = approximately 1.10

Let T_p = average gas temperature within the power cylinder

Let T_w = average water temperature within the jacket

Assume T_{pc} = 950 F

T_{wc} = 150 F

TD_c = 950 — 150 F = 800 F

Where TD = temperature difference

The temperature of the gas within the power cylinder is believed to be about 35 deg less.

Therefore T_{p_1} = 915 F

T_{w_1} = 212 F

TD_1 = 915 — 212 F = 703 F

The heat transferred in the conventional system then becomes

$$Q_c = (K_c)(TD_c)$$

Where K = overall heat transfer coefficient.

The heat transferred in the latent cooling system becomes

$$Q_1 = (K_1)(TD_1)$$

The ratio of heat transfer coefficients is

$$K_1 = \frac{Q_1/TD_1}{Q_c/TD_c}$$

$$\text{but } \frac{Q_1}{Q_c} = 1.10$$

$$= 1.10 \frac{\frac{1}{703}}{\frac{1}{800}} = 1.25$$

That means the K factor for latent cooling is 25 per cent higher than the K factor for conventional cooling. In a given system if the TD is changed the heat transfer (Q) changes. The conventional cooling system is known to provide adequate cooling. Therefore, the heat transferred by the latent cooling system can be reduced to equal that of the conventional cooling system and still provide adequate cooling.

Let Q_1' = new heat transfer rate = Q_c

$$Q_1' = Q_c = \frac{1}{1.10}(Q_1)$$

$K_1' = K_1$ because of the same system

$$\text{New } TD_1' = \frac{Q_1'}{K_1'}$$

$$= \frac{\frac{1}{1.10}(Q_1)}{K_1'} = \frac{\frac{1}{1.10} \times (K_1)(TD_1)}{K_1'}$$

$$= \frac{1}{1.10}(TD_1) = \frac{1}{1.10} \times (703) = 640 \text{ F}$$

TD_1 = 640 deg = $T_{p_1}' - T_{w_1}'$

The gas temperature within the power cylinder now becomes the same temperature for that of conventional cooling. That is because the heat transfer rate is the same.

T_{p_1}' = T_c 950 F

T_{w_1}' = 950 — 640 F = 310 F

310 F steam = 78 lb psia = 63 lb psig

Steam pressures of 63 lb are, therefore, now available with no changes in the present latent cooling system. Already engines have been operated at 26 lb with latent cooling.

What would happen if 200 lb steam were generated? The temperature difference through the engine cylinder wall into the jacket would tend to drop. That drop would cause a decrease in heat transferred. With less heat transferred the exhaust temperature tends to increase.

This increase in exhaust temperature should not produce any real problem. An increase in the temperature of the gas within the power cylinder would increase the possibility of preignition. Design changes might have to be made, but the automobile engine of today operates at much higher temperatures and compression ratios without preignition.

The engines that are being manufactured today will not withstand 200 lb pressure on water jackets. There is no reason why the engines could not be designed to meet these pressures.

Most of the available data to date concerning latent cooling has been obtained in the field. There is a need for development on the part of engine designers to realize fully the potentials of latent cooling. ★ ★ ★

Octane Rating Averages Climb

Results of July, 1955, survey of motor fuels by Du Pont show continued upping of octane ratings, by city averages.

	Octane Number				TEL Content	
	Motor		Research		cc/gal.	
	Pr	Reg	Pr	Reg	Pr	Reg
	July	July	July	July	July	July
Aberdeen, S. D.	85.1	80.9	92.7	86.1	2.54	2.00
Amarillo, Tex.	86.6	81.2	94.8	86.2	2.59	2.33
Atlanta, Georgia	86.7	83.4	96.9	89.2	2.31	2.62
Bakersfield, Calif.	85.5	80.2	95.1	85.5	2.89	2.56
Baltimore, Md.	86.5	82.8	96.8	91.0	2.45	2.16
Boston, Mass.	85.9	83.5	96.3	90.9	2.20	2.47
Calgary, Alta.	82.8	78.4	90.5	84.6	2.42	2.20
Casper, Wyo.	82.5	79.0	92.1	85.0	2.05	1.86
Charlotte, N. C.	85.8	82.9	96.4	88.9	2.32	2.52
Chicago, Ill.	86.0	82.6	94.8	88.1	2.36	2.27
Cincinnati, O.	85.5	83.4	95.1	89.9	2.37	1.82
Cleveland, O.	86.1	82.8	94.9	90.0	2.42	1.78
Columbus, O.	85.4	82.9	95.0	89.9	2.35	2.28
Corpus Christi, Tex.	87.9	83.8	96.6	87.7	2.85	2.41
Dallas—Ft. Worth, Tex.	86.8	81.8	96.9	87.0	2.84	2.75
Denver, Colo.	83.0	79.5	91.7	84.8	2.01	1.69
Detroit, Mich.	86.2	82.7	94.5	89.4	2.60	1.88
Edmonton, Alta	82.7	78.9	91.4	84.7	2.23	1.61
El Paso, Tex.	86.2	79.8	94.3	83.4	2.39	2.01
Great Falls—Billings, Mont.	83.0	79.3	93.9	86.1	2.18	2.16
Houston, Tex.	86.8	83.0	97.0	87.4	2.90	2.61
Indianapolis, Ind.	85.8	81.6	95.2	88.0	2.28	1.90
Jacksonville Fla.	86.5	83.0	96.6	90.2	2.37	2.39
Kansas City, Mo.	84.6	81.6	93.8	86.2	2.38	2.14
Little Rock, Ark.	86.4	83.2	96.8	88.7	2.82	2.79
Los Angeles, Calif.	84.0	79.3	95.4	85.7	2.55	1.68
Louisville Ky.	85.8	82.9	96.5	88.9	2.73	2.57
Memphis, Tenn.	86.2	82.7	96.7	89.1	2.63	2.29
Milwaukee, Wisc.	86.0	82.2	95.3	88.7	2.50	2.32
Minneapolis, Minn.	85.2	81.8	94.3	86.2	2.41	2.08
Montreal, Que.	84.0	82.0	94.3	88.7	2.46	1.53
Nashville Tenn.	85.6	82.8	96.8	88.6	2.70	2.57
New Orleans, La.	86.5	82.7	96.8	88.6	2.92	2.49
New York, N. Y.	86.2	83.3	96.6	90.6	2.48	2.27
Omaha, Neb.	85.3	81.5	93.9	86.4	2.67	2.40
Philadelphia, Pa.	86.0	82.8	96.8	90.7	2.07	1.95
Pittsburgh, Pa.	86.4	83.3	96.1	90.4	2.33	2.38
St. Louis, Mo.	84.6	81.5	94.0	86.0	2.46	2.55
Salt Lake City, Utah	82.2	78.2	90.8	82.4	1.41	1.70
San Francisco, Calif.	85.6	79.4	95.7	86.3	2.52	1.35
Seattle, Wash.	84.8	80.6	95.0	85.8	2.43	1.47
Shreveport, La.	86.8	83.2	96.6	88.2	2.81	2.76
Spokane, Wash.	84.6	80.2	95.5	86.4	2.32	1.35
Toronto, Ont.	85.1	81.8	94.2	88.4	2.55	1.45
Tulsa-Okla. City, Okla.	85.7	81.5	93.8	85.9	2.59	2.04
Vancouver, B. C.	84.2	80.1	93.9	85.2	2.70	2.30
Wichita, Kan.	85.3	81.2	93.6	85.7	2.30	1.76
Winnipeg, Man.	83.5	80.3	93.1	86.0	2.27	1.86

Determination of Total Carbon Dioxide by Evolution

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MANY methods have been proposed for the determination of carbon dioxide in various substances. The determination of carbon dioxide in carbonates and bicarbonates is generally conducted by means of some quantitative measure of the carbon dioxide evolved upon acidification of the sample. Scott and Jewell[4] describe a method based on loss of weight after acidification. Although rapid and simple, this procedure lacks the accuracy often needed. Methods capable of high accuracy have been described that determine the evolved carbon dioxide by gravimetric,[2] gasometric,[3] and titrimetric[1] techniques. These methods, however, require more elaborate equipment and are more time consuming than the procedure presented here.

This method is intended for the determination of total carbon dioxide, free or combined, in any substance from which carbon dioxide can be liberated by treatment with strong mineral acid. The method is, therefore, applicable to practically all metal carbonates and bicarbonates whether solid or in solution. It is particularly advantageous for use where direct acidimetric titration of carbonate and bicarbonate is not practical because of the presence of various interfering substances, such as the anions of weak acids.

Accurate results may be obtained on a wide variety of materials, such as pure carbonates or solutions containing minute quantities of carbon dioxide, by varying the sample size from a few milligrams to 100 grams or more.

Theory and Development of Method

Carbonates and bicarbonates are decomposed by acids to give free carbon dioxide, which is then absorbed in a known excess of hydroxyl ions in a solution containing an excess of barium chloride. Barium carbonate is thus formed.

$$CO_2 + 2OH^- + Ba^{++} = BaCO_3 + H_2O$$

The unreacted excess hydroxide is then titrated with a standard acid.

The present method employs a very convenient apparatus assembly mounted on a single ring stand in which the absorption of carbon dioxide and titration of the excess alkali are conducted in the same vessel without the necessity of disassembling the apparatus. Thymolphthalein is used as the titration indicator because it affords a much sharper end point than phenolphthalein, even without using an alcoholic solution, or removing the precipitated barium carbonate.

Apparatus

The apparatus is shown in the accompanying diagram. In addition to the equipment shown, a small burner or hot plate is needed to heat the reaction flask. A source of vacuum is also needed.

Reagents

1. Barium Chloride, 10 per cent solution in water.
2. Sulfuric Acid, dilute (1:1).
3. Hydrochloric Acid, Standardized, 0.05N.
4. Ascarite.
5. Cadmium Sulfate, granular.
6. Sodium Sulfate, anhydrous.
7. Sodium Hydroxide, approximately 0.05N. The standard N/16 sodium hydroxide used for the lamp sulfur determinations is convenient. Carbonate free reagent is preferred, but is not essential because a blank is conducted.
8. Thymolphthalein Indicator Solution. Make a 0.1 per cent solution in 50 per cent ethyl alcohol. Neutralize by adding dilute NaOH until faintly blue or green and then just barely discharge the color with 0.05N HCl.

Procedure

Reagent and Operating Blank. Assemble the apparatus as shown in the diagram but omit the solution in the absorber and reaction vessel. Run a slow stream of cold water through the condenser jacket. Connect to the vacuum line, open stopcocks "1" and "2" (Note 1) and draw a slow stream of air through the apparatus for about 10 minutes. Close stopcock "2" and add 50 ml of freshly boiled CO_2-free distilled water directly to the reaction flask. Replace the reaction flask, close stopcock "1" and add to the bulb 10 ml of (1:1) sulfuric acid and 25 ml of CO_2-free distilled water.

To the absorber add 5 ml of 10 per cent barium chloride solution, 50 ml of CO_2-free distilled water, about 5 drops of thymolphthalein indicator and enough accurately measured sodium hydroxide solution to give a blank of about 24 ml of 0.05N hydrochloric acid (19.0 ml of N/16 NaOH = 23.75 ml of N/20 HCl). Stopper quickly to avoid absorption of atmospheric CO_2. The burette should be filled with 0.05N HCl and leveled before filling the absorber.

Open stopcock "2." Now slowly open stopcock "1" so as to add the diluted acid slowly to the reaction flask. When all of the acid has run into the reaction flask adjust stopcock "2" so that a slow stream of air (Note 2) passes through the system. Cautiously

EXCLUSIVE

heat the reaction flask to boiling (Note 3) and boil for one or two minutes and then draw air through the system for another 30 minutes. Titrate the absorber solution, while still maintaining the flow of air, until the blue color just disappears.

Sample Runs. Weigh into the reaction flask a quantity of sample estimated to contain less than 24 mg of CO_2. Optimum size of sample is such as to contain 10 to 20 mg of CO_2-free water to bring the volume to approximately 50 ml. Assemble the apparatus and conduct the test as for the blank above, but do not heat the reaction flask until the initial rapid evolution of CO_2 has subsided appreciably.

Calculations

$$\% CO_2 = \frac{(B - T) \times 2.20\,N}{W.}$$

where:

B = Ml of standard HCl for the blank.
T = Ml of standard HCl for the sample.
N = Normality of standard HCl.
W = Weight of sample in grams.

If N = 0.0500,

$$\% CO_2 = \frac{0.110\,(B - T)}{W.}$$

Summary

The U-tube shown in the diagram contains a mixture of 50 per cent cadmium sulfate and 50 per cent anhydrous sodium sulfate. The cadmium sulfate will remove any hydrogen sulfide that might be evolved from the sample, and the anhydrous sodium sulfate will absorb moisture to keep the cadmium salt from caking and creating an excessive resistance to the flow of gases.

The presence of nitrites in the sample will interfere with the method. The interference may be eliminated by the addition of a few crystals of potassium permanganate to the reaction flask before the acid is added, however. This treatment should also oxide any sulfides which might be present.

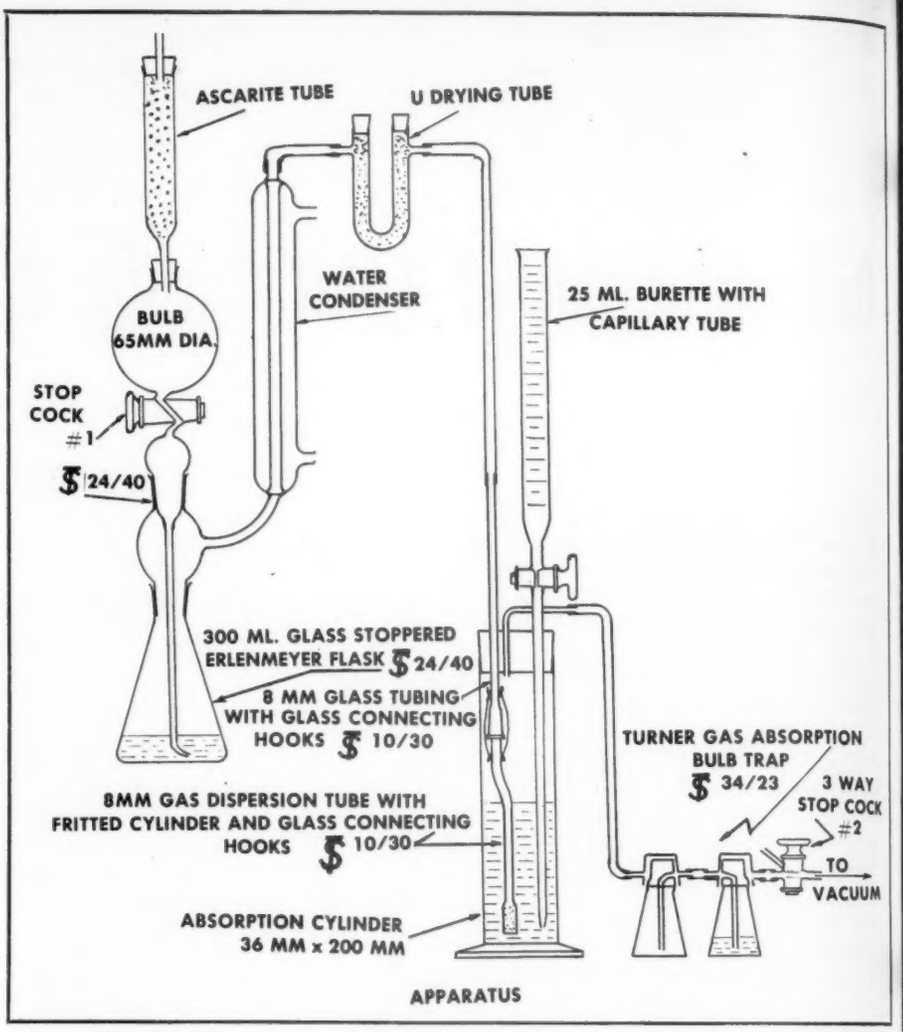
In general the presence of any substance other than carbonate yielding either acidic or basic vapors will invalidate the method unless appropriate modifications are made. For instance, ammonium salts or volatile amines would interfere by causing low results and indistinct end points. This would be eliminated by the addition of a trap containing dilute sulfuric acid to be placed between the condenser and the cadmium sulfate tube.

For some samples it is possible to eliminate the use of freshly boiled CO_2-free water by substituting the same quantities of the same distilled water in both the blank and the sample runs. This procedure suggests itself for application to solid samples and to liquid samples where at least 50 ml of additional water may be added to the reaction flask. It is desirable that CO_2-free water be used in the procedure as given for most accurate results, however.

For accurate results it is essential that precautions be taken to prevent the absorption of atmospheric carbon dioxide when handling and filling the absorber with the sodium hydroxide.

At the end of the sample run there must, of course, be some unreacted hydroxide present in the absorber to be sure that all the evolved carbon dioxide has been absorbed. Therefore, if the back titration with the 0.05N HCl does not amount to one or two ml, the test should be repeated using a smaller sample. If many very high CO_2 content samples are to be run, it may be advantageous to employ more concentrated solutions.

Pure samples of sodium carbonate and calcium carbonate were analyzed to check the method. Results are given in Table 1.


ASCARITE TUBE
U DRYING TUBE
WATER CONDENSER
25 ML. BURETTE WITH CAPILLARY TUBE
BULB 65MM DIA.
STOP COCK #1
24/40
300 ML. GLASS STOPPERED ERLENMEYER FLASK 24/40
8 MM GLASS TUBING WITH GLASS CONNECTING HOOKS 10/30
TURNER GAS ABSORPTION BULB TRAP 34/23
3 WAY STOP COCK #2
TO VACUUM
8MM GAS DISPERSION TUBE WITH FRITTED CYLINDER AND GLASS CONNECTING HOOKS 10/30
ABSORPTION CYLINDER 36 MM x 200 MM
APPARATUS

Details of apparatus used for "Carbon Dioxide by Evolution" method.

TABLE 1.

Sample	*Theory, % CO_2**	*Found, % CO_2*
Na_2CO_3	41.09	41.07
		41.08
$CaCO_3$	43.83	43.73
		43.87

*Corrected for assay purity

Notes

Note 1. The rate of flow of air through the system should be regulated at stopcock "2" with the three-way stopcock open both to the atmosphere and the system. Stopcock "1" should always be left wide open during a run. This procedure prevents putting the system under high vacuum, provided the traps are kept free flowing.

Note 2. The loss of CO_2 through incomplete absorption is the result of too rapid passage of gas through the absorber. For complete absorption, the gas passage through the fritted glass dispersion tube should be at such a rate that bubbles in the trap are of the order of 120 per minute.

The trap contains approximately 25 ml of distilled water to which has been added 0.3 to 0.5 ml of standard 0.05N NaOH and 3 or 4 drops of thymolphthalein indicator. The fading of color in the trap indicates incomplete absorption of CO_2 in which case the gas rate must be slowed down.

Note 3. Heat the reaction flask slowly to prevent the acid mixture from rising into the bulb with consequent loss of CO_2.

References

1. American Society for Testing Materials, Philadelphia, Pennsylvania. *1952 Book of ASTM Standards*, Part 7, ASTM Tentative Method D513-50T, pp 1135-40, 1953.
2. Scott, W. W., (N. H. Furman, Editor): *Scott's Standard Methods of Chemical Analysis*, 5th ed., Vol. I, pp 235-7, D. Van Nostrand Company, New York, New York, 1947.
3. ibid, pp 240-2.
4. Scott, W. W., and Jewell, P. W.: *Ind Eng. Chem., Anal. Ed.*, Vol. 2, 76 (1930). ★★

P 200.

Oil-Water Emulsions

Their Composition and How To Treat Them

Part IV

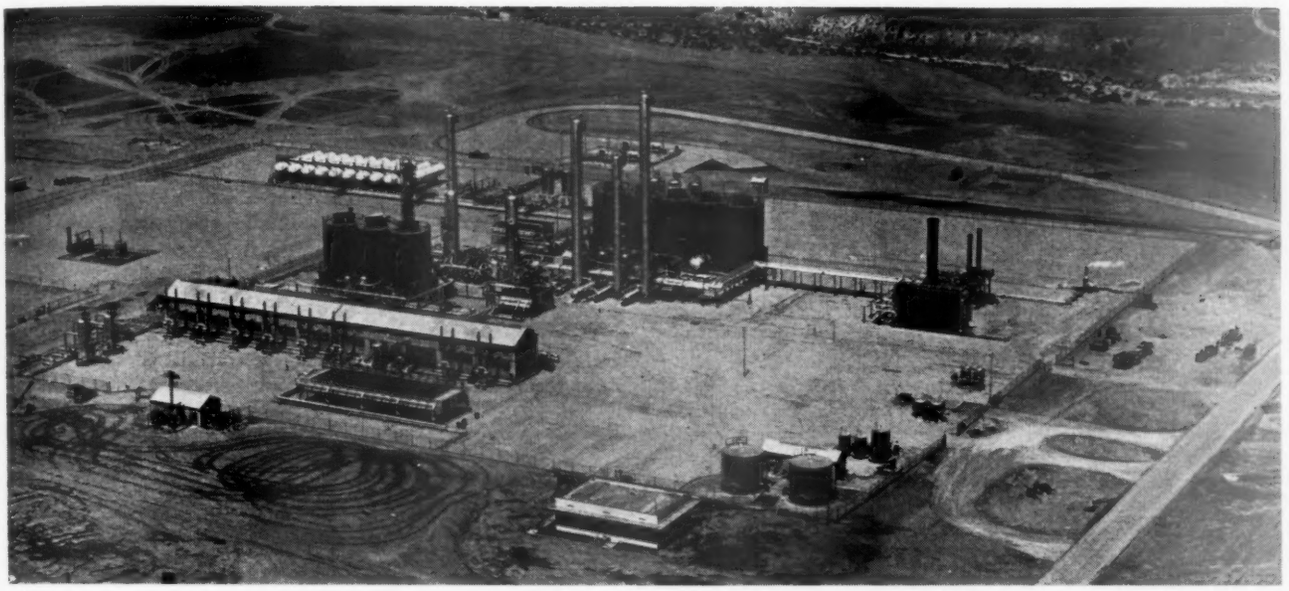


FIG. 1. Construction here typifies the modern natural gasoline recovery plant. *Richfield Oil Corporation*

Natural Gas, Hydrocarbons Found Therein and Methods for Their Recovery

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Consulting Chemical Engineer

WHEN crude oil reaches the surface it usually contains water and carries natural gas. As the field grows older, in most case the proportion of water increases and that of the gas decreases.

Emulsions and How to Break Them

Water is normally present at the bottom of the oil "pool" below the oil level. When the oil is removed and gas pressure declines, water often works its way up to the oil and contaminates the well stream. The quantity of water in the crude oil may vary from zero to a few per cent to 50 per cent or more, depending on the locality and age of the field. (Fig. 1) It is costly to remove this water from well production.

Water and oil do not mix. They may be made to disperse in each other in very fine droplets, however. Such dispersions are formed when oil and water are lifted from the ground. They are known as emulsions and contain small globules of water surrounded by the oil. The emulsions are usually of a lighter color than crude oil and may have a milky appearance. To the naked eye these emulsions seem to be quite uniform and homogeneous but under a microscope their true nature is revealed. The oil producer is confronted with the problem of separating the oil from such emulsions. This must be done before the crude oil is shipped to the refineries or pumped to storage. The method of accomplishing this must be cheap, because crude oil is not an expensive commodity. In the field, heat and chemicals are employed largely to separate water from crude.

In the refinery the most common method of "breaking" or separating crude oil emulsions is by electrical precipitation. Direct or alternating current can be used to do it. The emulsion is usually warmed to make it more fluid and to reduce its stability before the electric current is applied.

Direct current of high voltage electrifies the water droplets. As opposite charges attract each other, the droplets move toward the electrodes having charge opposite in electric sign to that of the droplets. The droplets have a negative charge and move toward the positive electrode. Here they unite, forming big droplets of water that settle

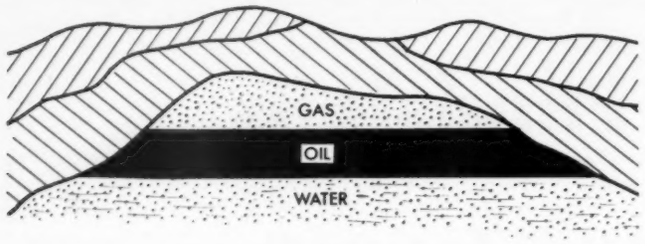


FIG. 2. Cross-section of an oil deposit, or "pool," showing relative positions of gas layer, oil layer and underlying water layer as found naturaliy.

out from the oil. However, for breaking oil field emulsions alternating current is usually employed that works on a different principle.

When *alternating current* is applied the charge on the electrodes reverses many times per second, causing corresponding changes in the direction in which the droplets are moving. These vibrations disrupt the oil film around the water droplets which combine into larger droplets. The large droplets settle out from the oil due to their increased weight.

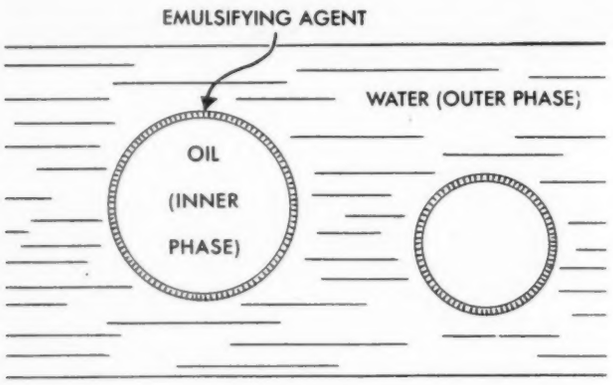
Another method of breaking emulsions involves the use of chemicals. According to present theory, emulsions consist not only of oil and water but also of an emulsifying agent, that is, a substance that promotes the formation of emulsions. For instance, if we shake a well refined oil with water, the resulting mixture separates upon standing. If we add a very small quantity of ordinary soap before the mixture is shaken, however, a stable emulsion may be produced, the soap being the emulsifying agent.

The emulsifying agent envelops the surface of the water droplets, forming a layer acting like a shield that prevents the individual droplets of water from combining. This is illustrated in Fig. 3A, 3B, 3C, and 3D. To break the emulsion it is therefore essential to destroy or to neutralize the action of the emulsifying agent. This can be done because the emulsifying agents are of two types. Some of them form emulsions containing oil droplets surrounded by water (Fig. 3A), while others form emulsions containing water droplets surrounded by oil (Fig 3B). Complex emulsions also exist that contain another emulsion as an inner phase (Fig. 3C). Such emulsions are unstable unless they are prepared artificially. The water or oil droplets in an emulsion are in the form of spheres but occasionally they are of odd shapes as shown in Fig. 3D, which is an indication that the emulsion is on the point of breaking. It is of interest that addition of water to a water-in-oil emulsion or oil to an oil-in-water emulsion weakens the emulsion because the emulsifying agent has to spread over a larger area of droplets, while addition of the substance in which the droplets are suspended has no effect or may even increase the emulsion stability.

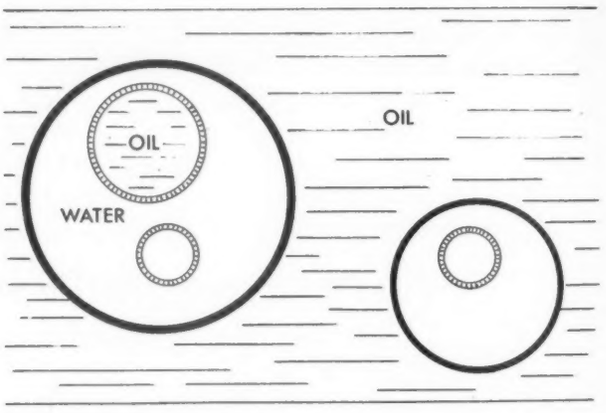
Ordinary soap, which is a combination of sodium or potassium with a fatty acid, produces an oil-in-water emulsion (Fig. 3A) but if the sodium is replaced with calcium the resulting emulsion will be of water-in-oil type (Fig. 3B). It may be readily seen that emulsifying agents responsible for one type of emulsion have the ability to break the other type of emulsion. This is the principle of the chemical method of treating emulsions.

Both the water-in-oil and the oil-in-water types of emulsion are encountered in the petroleum industry. The water-in-oil type is represented by the oil-field emulsions and the

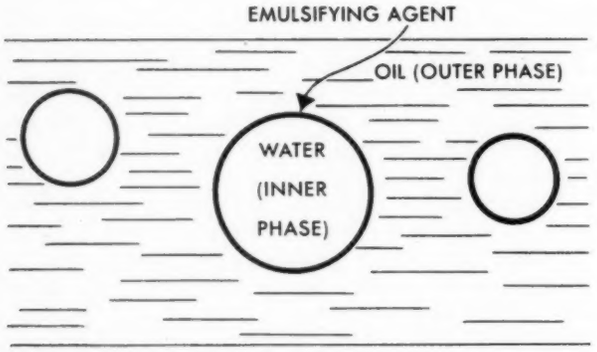
FIG. 3. These four types of oil-water emulsions exist:



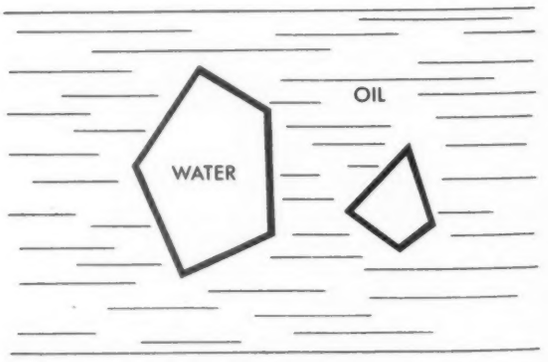
A. Oil-in-water emulsion, where the oil is in unconnected drops or droplets dispersed in water;



C. A complex emulsion, partly water-in-oil and partly oil-in-water, that is normally unstable;



B. Water-in-oil, where the water is in droplets, unconnected, and with oil as the "continuous phase;"



D. Unusual emulsion, containing distorted droplets in the inner or discontinuous phase, also indicative of instability.

oil-in-water type is encountered in the course of petroleum refining.

Application of chemical methods for breaking emulsions is much more complicated in practice than in theory. The nature of the emulsifying agent in oil-field emulsions varies with the crude oil but fine particles of clay and asphaltic substances in the oil are the chief offenders. This does not simplify the matter of breaking emulsions with chemicals. For no apparent reason, some demulsifying agents are very effective in breaking one emulsion but are not suitable for breaking another. The choice of an emulsifying agent is therefore made on the basis of experimental work with the emulsion under treatment.

A very large number of demulsifying agents is available for treating crude oil emulsions. They are usually sodium soaps of fatty acids or of sulfuric acid reacted with organic materials. Mixtures of several chemicals are often used. For instance, one of the commercial demulsifying agents was found to have the composition shown in Table 4A.

TABLE 4A. Chemical composition of a commercial demulsifying agent.

Sodium oleate	83.00 % by wt
Sodium resinate	5.50 % by w
Sodium silicate	5.00 % by wt
Phenol	4.00 % by wt
Paraffin	1.50 % by wt
Water	1.00 % by wt
	100.00

The composition of demulsifying agents is not advertised because a considerable amount of work is needed for developing efficient and inexpensive formulations. Many of the demulsifying agents are sold under the trade name of "Tret-o-lite."

Heating emulsions always reduce their stability, that is, their ability to "stay put." The water can be expelled from the oil by distillation if special stills are employed to prevent foaming. This method is suitable for all types of emulsions, but is little used in practice because of expense and other limitations. Centrifuging and filtering have been recommended, but they are seldom economical.

Water is not the only impurity in the crude oil that must be removed in order to insure successful processing of crude oil in the refineries. Some of the crude oils contain considerable quantities of mineral salts, such as sodium or magnesium chlorides. Vanadium compounds are particularly objectionable. These mineral salts may form deposits in the distillation equipment or cause corrosion. Their elimination is desirable before the crude oil is distilled.

Mineral salts can be removed from crude oil by washing with water and settling the resulting salt solutions. Difficulties may be encountered in separating these solutions due to formation of emulsions. A particle of dry salt surrounded by the oil is much more difficult to wash out than a water droplet that contains the salt in solution. These emulsions can be broken in the same manner as oil-field emulsions, because both are of the water-in-oil type. If heating alone is insufficient, processes such as the Petreco electrical desalting process or the Howe-Baker process may be installed. In these processes the wash water is separated from the oil by passing the emulsion through an electric field, as in the electrical dehydration method. While the removal of water from oil-field emulsions is always done in the field, desalting is frequently carried out at the refineries. In some instances it is more profitable to conduct it in the field also, because of the similarities between the desalting and dehydrating operations.

Natural Gas—Natural Gasoline

Natural gas is associated with the crude oil but large natural gas fields may exist by themselves. Gas wells are drilled for exploiting these sources of fuel. The size of some of the gas fields may be visualized from the following figures pertaining to the Hugoton-Guymon field, located in Texas, Oklahoma, and Kansas. It is the largest dry gas field in the world. The field is 150 miles long and 35 miles wide, covering an area of 3,850,000 acres. It contains 25 trillion cubic feet of gas. This quantity is sufficient for supplying enough heat to melt a square mile of ice 100 ft thick.

We usually assume that composition of natural gas is uniform, regardless of the location of gas or oil fields. Actually the composition varies within wide limits. Gas obtained from wells may contain as much as 98 per cent carbon dioxide (Mora County, New Mexico), or it may be almost pure nitrogen (Weld County, Colorado, or Alfalfa County, Oklahoma). It may contain up to 16 per cent helium (Musselshell County, Montana). If the natural gas consists, as it almost always does, of hydrocarbons, the nature of these hydrocarbons may vary within wide limits.

Some of the gas wells yield practically pure methane, a gas that cannot be condensed into a liquid at room temperature under any conditions. Other wells may contain methane in admixture with other hydrocarbon gases like ethane or propane. Still other wells may produce large volumes of vapors of normally liquid hydrocarbons representing light gasoline fractions. Gas containing such vapors is referred to as "wet gas" or "rich gas," to distinguish it from "dry gas" or "lean gas" which is essentially free from them. If these vapors are condensed, the quantity of gasoline recovered may vary from a fraction of a gallon to several gallons per 1000 cu ft of gas, making their recovery in many instances a paying proposition.

Recovery of these heavier hydrocarbons is in the hands of the natural gasoline industry. Over 660,000 bbl of natural gasoline were produced daily in 1953; production has tripled every eleven years for three decades. Removal of gasoline vapors from natural gas used for heating purposes is required also because of potential fire hazard. Under variable temperature and pressure conditions, gasoline vapors may condense into liquid, and when droplets of such liquids reach flame they may cause violent explosions.

Hydrocarbons present in natural gas are of the saturated type similar to methane. The greater the number of carbon atoms in the molecule, the higher the boiling point. These hydrocarbons include ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}) and the heavier ones in decreasingly smaller quantities.

Ethane is a gas similar to methane. Propane, which is also a gas under normal conditions, however, may be liquefied by applying considerable pressure. Butane liquefies with still greater ease because its boiling point under normal atmospheric pressure is still higher, close to the freezing point of water. Propane and its mixtures with butane known to the public as "butane gas," are used as substitutes for gaseous fuels in the regions where domestic gas via pipe line is not available. In 1922 the quantity of this liquefied petroleum gas (LPG) sold as a novel domestic fuel was 223,000 gal. In 1940 its consumption rose to 313,000,000 gal and in 1950 to 3,483,000,000 gal. It was 5,134,000,000 gal in 1954. New uses for this commodity developed. While in 1922 the liquefied petroleum gas was used exclusively in homes and was a novelty, in 1954 only about half of its production was utilized for this purpose. One quarter was consumed by the synthetic rubber and other chemical industries and the rest found applications as industrial fuel or as fuel for tractors, trucks, and buses.

For distributing to individual households in rural districts the liquefied gas is pumped under pressure into cylinders and thus transported to the customers. Small towns vaporize the liquefied gas and feed it into their central distributing systems.

Liquid hydrocarbons present in natural gas and boiling within the gasoline range are sold under the name of "nat-

ural gasoline." Previously, this gasoline was known as "casinghead gasoline," but this name is now obsolete. Motor fuel sold at the service stations is a blend of various petroleum products, including natural gasoline or its equivalents.

Recovery of Fuels From Natural Gas

Several methods have been developed for the recovery of liquefiable or liquid hydrocarbons from natural gas. The oldest method is the compression method. It is somewhat obsolete but new improvements may restore its original importance.

Natural gas is compressed until the heavy hydrocarbons are liquefied. The higher the pressure and the lower the temperature, the greater is the liquid recovery. Compressors are expensive and water used for cooling the compressed gas may be scarce in a given locality. Optimum economic conditions must be established for each individual plant depending on the composition of the gas processed. The minimum pressure required is still measured in hundreds of pounds per square inch and the expense involved must be charged to the natural gasoline production. With the development of high pressure gas lines the cost of compression is included in the transportation cost and this reduces the cost of the natural gasoline recovery process. Natural gasoline produced by compression is sometimes referred to as "compression gasoline."

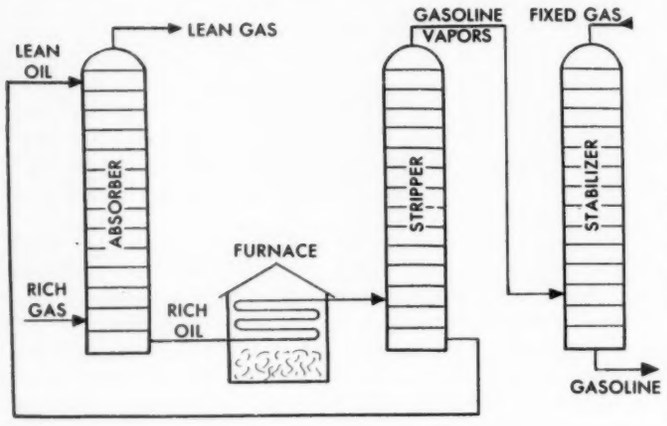


FIG. 4. Simplified flow chart of a natural gasoline plant, showing the steps required in the recovery of light hydrocarbons—propane and heavier—from natural gas; the same steps are employed in recovery of the same materials from refinery off-gases. (Vapor recovery).

The compression method has been to a great extent superseded by the absorption method. This method is based on the principle that the heavier hydrocarbons are more easily dissolved by petroleum fractions than the lighter ones. The "wet gas," i.e. natural gas containing gasoline vapors, is intimately mixed with a petroleum fraction, known as "absorption oil," usually a light grade of kerosine or naphtha, in a specially designed absorption tower. Fig. 4 illustrates this process.

The nature of the hydrocarbons and the extent to which they are dissolved or absorbed by the "absorption oil," are controlled by adjusting pressure, temperature and the rate of flow through the tower. Absorption oil containing the dissolved hydrocarbons, and usually referred to as "rich oil," is preheated and pumped into another tower to vaporize the absorbed gasoline. The gasoline vapors are passed to a stabilizer. This is a still designed for separating the lightest hydrocarbons, like ethane or propane, from the rest. If these light hydrocarbons are left in the gasoline they will develop pressure in storage tanks and escape into the air unless special equipment is used to prevent their evaporation. The "lean oil," i.e. absorption oil after being freed from gasoline, is returned to the absorption tower to repeat the cycle. Natural gasoline thus recovered is called "absorption gasoline."

A third adsorption method has been developed to accomplish the same purpose, but its commercial use is very limited. "Adsorption" differs from "absorption" in that the liquid hydrocarbons are removed by solids and not by liquids. Natural gas from the wells is passed through towers filled with a solid substance capable of retaining gasoline vapors in preference to the gaseous hydrocarbons. Special grades of carbon or silica gel were suggested for this purpose.

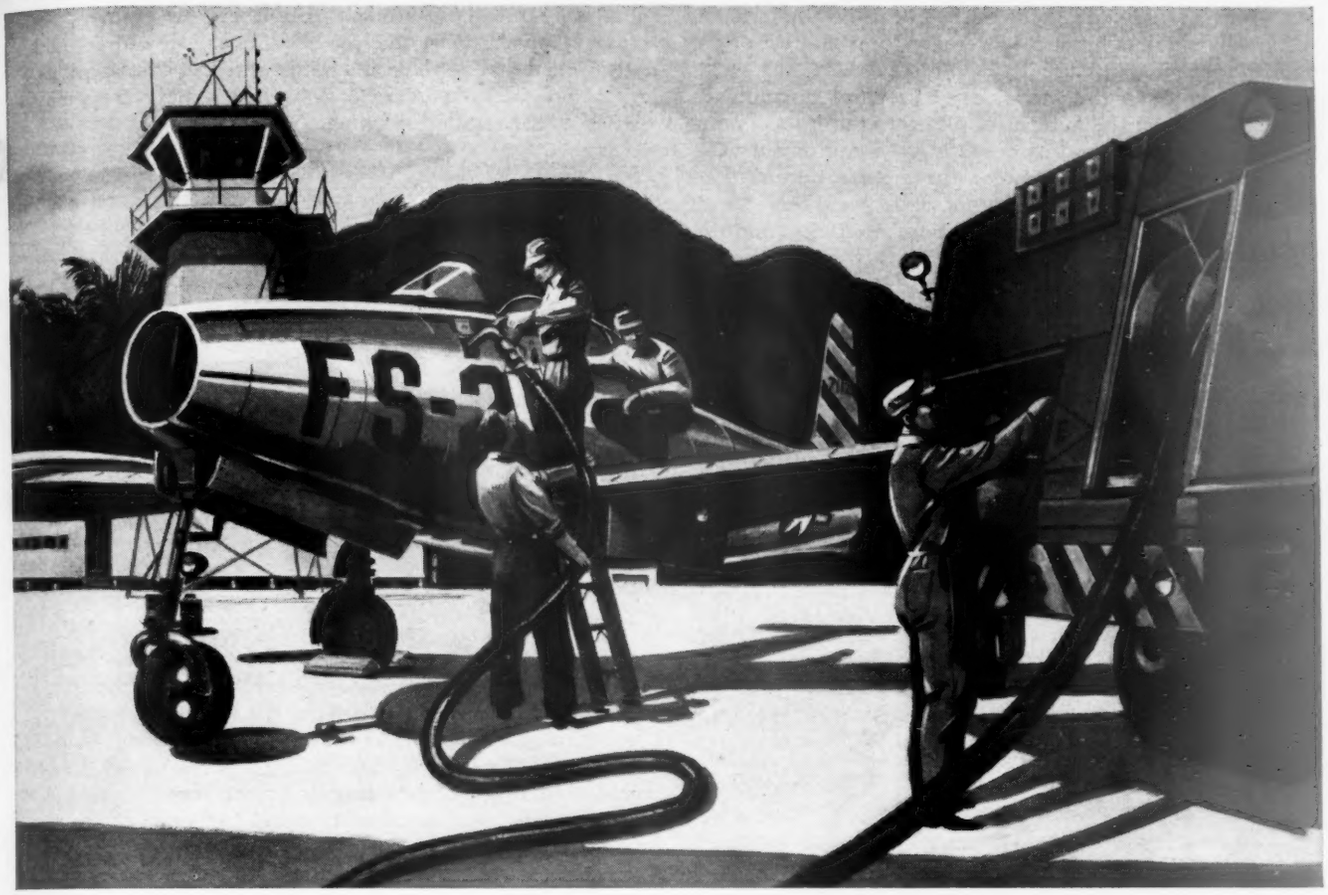
When the adsorbent is saturated with gasoline, the gas is diverted into another tower and the gasoline is recovered by blowing the first tower with steam and condensing the liberated gasoline vapors. Three towers are required to insure an uninterrupted flow of gas through the plant. Natural gasoline obtained by this process is known as "adsorption gasoline."

The ability of charcoal to adsorb heavy hydrocarbons in preference to the lighter ones is utilized for separating individual hydrocarbons from each other by the hypersorption process of the Union Oil Company. After the hydrocarbons are adsorbed, the charcoal is heated with steam under conditions when only one substance is given off at a time. The method is satisfactory for use with gaseous hydrocarbons. The presence of unsaturated hydrocarbons must be avoided because their molecules unite with each other, i.e., polymerize and form high boiling substances that are not removed from charcoal by steam.

Large refineries are equipped with plants for the recovery of gasoline vapors from the gaseous hydrocarbons that are produced from the distillation and cracking units or evaporate from storage tanks. Such plants are frequently called "conservation plants" and their products are known as "conservation gasoline." Natural and conservation gasolines often contain considerable quantities of dissolved hydrocarbon gases that evaporate at a much faster rate than the liquid gasoline hydrocarbons. On evaporation, the gases may carry away a large proportion of valuable liquid hydrocarbons, thus causing high storage and handling losses. The presence of dissolved gases is also undesirable if natural gasoline is used for the preparation of the motor gasoline. Separation of gaseous from liquid hydrocarbons is, therefore, very important in commercial practice. This separation is accomplished by the "stabilization processes" and the resulting gasoline is referred to as "stabilized gasoline."

What Is "Fractional Distillation?"

Stabilization of gasoline consists in separating gaseous and liquid hydrocarbons by what is known as fractional distillation. Fractional distillation differs from straight distillation in that the vapors given off are passed through a column containing a number of plates of special design, as shown in Fig. 5. The plates have narrow passages for gases and vapors flowing upward. These passages are in the "bubble caps." The "overflow pipes" are reserved for liquid traveling downward. At each plate the vapors condense and the resulting liquid partially revaporizes. The newly formed vapors ascend to the next higher plate of the fractionating column, while the unevaporated fraction flows downward to the next plate below. After each revaporization the ascending vapors become progressively richer in the low-boiling materials, while the liquid descending the column becomes progressively richer in the high-boiling materials. The process thus permits separation of gasoline hydrocarbons into groups that boil within a narrow temper-



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ature range. Individual hydrocarbons can be separated if their boiling points differ considerably from the rest of the hydrocarbons in a mixture.

How close the hydrocarbons can be separated from each other depends on the number of plates in the fractionating column and the method of operating the equipment. The greater is the difference between the top and bottom temperatures in a fractionating column, the larger is the volume of the liquid flowing down the fractionating plates and the sharper is the separation in the boiling points of the oil fractions. The liquid flowing down the plates is known as "reflux".

The boiling ranges of the fractions obtained in distillation may "overlap" or a "gap" may exist between the temperatures at which one fraction evaporates completely and the next fraction starts boiling. The smaller the overlap or the larger the gap, the more efficient is the fractionation. For increasing the temperature difference between the top and the bottom of the column, a portion of the product may be returned from the receivers to the top of the column in order to provide an "outside reflux."

Stabilization of gasoline results in the reduction of its vapor pressure, i.e. the pressure that is registered when gasoline is confined in a closed vessel under prescribed conditions of testing. The name of the apparatus should be specified because the results obtained may vary with the equipment used. The desired vapor pressure is obtained by varying the content of lighter hydrocarbons, for example,

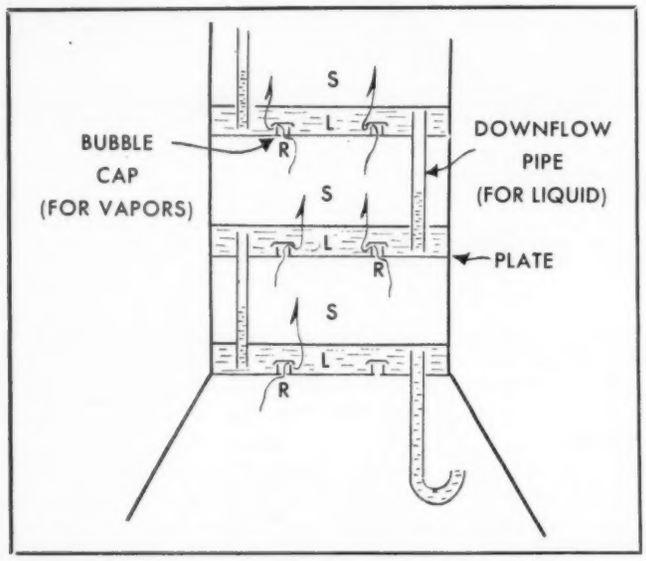


FIG. 5. Diagrammatic representation of the essential parts and action of bubble plates used in fractionating columns; vapor passes upward through risers, r; reverses through slots in top of risers, and again upward through layer of liquid, l; upward through open space, s, then repeat the action on the next plate.

propane and butane. In general, propane is an undesirable constitutent of gasoline in the engine in any proportions. If gasoline contains an excess of butane, this excess may be separated and then added to another gasoline deficient in butane. Such "transpositions" are common in manufacturing commercial gasolines in petroleum refineries. When propane is removed, the process is referred to as the "depropanizing process" and the fractionating column in which this is accomplished is known as a "depropanizer." When butane is removed, the process is referred to as the "debutanizing process," and the equipment is known as a "debutanizer." Similary "deethanizer" is employed for separating ethane and "dependanizer" for separating pentane, a hydrocarbon boiling at a higher temperature than butane.

The boiling points of some of the saturated open-chain paraffin hydrocarbons are shown in Table 4B. Isomers, i.e. hydrocarbons having the same number of carbon and hydrogen atoms in a molecule but in different combinations, are included in the table to show how widely they may vary from each other in boiling points.

TABLE 4B. Boiling points or paraffin hydrocarbons.

Hydrocarbon	Formula	Boiling point, °F
Methane	CH_4	—258.5
Ethane	C_2H_6	—128.2
Propane	C_3H_8	—43.8
Butanes:	C_4H_{10}	
n-butane	n-C_4H_{10}	31.9
isobutane	iso-C_4H_{10}	10.9
Pentanes:	C_5H_{12}	
n-pentane	n-C_5H_{12}	96.8
isopentane	iso-C_5H_{12}	82.2
neopentane	neo-C_5H_{12}	49.0
Hexanes	C_6H_{14}	121.5—156.0
n-hexane	n-C_6H_{14}	156.0
Heptanes	C_7H_{16}	174.7—209.2
n-heptane	n-C_7H_{16}	209.2
ctanes	C_8H_{18}	210.4—258.1
n-octane	n-C_8H_{18}	258.1
Nonanes (a)	C_9H_{20}	259.1—303.3
n-nonane	n-C_9H_{20}	303.3
Decanes (a)	$C_{10}H_{22}$	158.0—345.2
n-decane	n-$C_{10}H_{22}$	345.2

(a) Not all of them are known.

Only one hydrocarbon is shown among the paraffins having more than six carbon atoms because they multiply rapidly with the increase in the number of carbon atoms in a molecule. There are 5 known hexanes, 9 heptanes, and 18 octanes; a few more might be discovered eventually. Theoretically, at least 35 nonanes and 75 decanes should exist but not all of them are known. The table shows, however, that hydrocarbons belonging to the same series and having a larger number of carbon and hydrogen atoms in a molecule may boil at much lower temperatures than the hydrocarbons made up of a smaller number of atoms in a molecule. The boiling points of normal hydrocarbons, i.e. hydrocarbons that have all the carbon atoms in a single chain, always increase with the number of carbon atoms in a molecule. They boil at higher temperatures than the rest of the hydrocarbons having the same number of carbon and hydrogen atoms.

If butane is added to gasoline to increase its vapor pressure, the operation is called "repressuring." Under certain conditions propane and butane may be removed from the gasoline as a mixture and butane may be then "depropanized", i.e. separated from propane. The above shows that at a refinery the hydrocarbons are first separated into groups that are then reblended in proper proportions to meet the product specifications.

If two substances have boiling points very close together, their separation may not be possible even in fractionating columns containing a large number of plates. In some instances this can be done by the so-called "azeotropic distillation" method, however. This method involves addition to the mixture of a third substance such as alcohol, acetone, furfural, phenol, and others. The substance is selected from among those that form a constant-boiling mixture with one of the constituents of the original mixture.

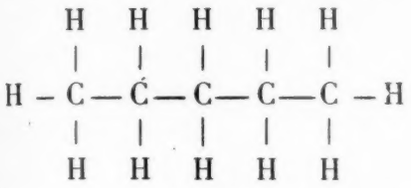
This means that, on boiling, both substances vaporize simultaneously, dragging each other out of the solution away from the other substances because of their mutual affinity. For instance, assume that the original mixture consists of components A and B having the same boiling point. By adding the azeotropic agent C which has affinity for A, a mixture of A and C will distill off at a different temperature than the boiling point of A and B, thus making the separation possible. A is then separated from C by some other method than distillation, such as dissolving C in water or other solvent in which A is insoluble. Processes of this type, known as "azeotropic processes," are used for preparing pure hydrocarbons from petroleum.

For instance, benzene and cyclohexane boil at 176.2 F and 177.4 F respectively. This is only 1.2 F apart and no

commercial equipment has yet been built that can separate such close boiling substances by fractional distillation. However, the two hydrocarbons form azeotropes with acetonitrile, a compound of carbon, hydrogen and nitrogen, which boils at 178.9 F. The benzene-acetronitrile azeotrope contains 57 per cent benzene by volume and boils at 165.9 F. The cyclohexane-acetonitrile azeotrope contains 67 per cent cyclohexane by volume and boils at 144 F. The spread in boiling points between the two azeotropes is 21.9 F and they can be separated by distillation. After the azeotropes are condensed, acetonitrile is extracted from the hydrocarbons by dissolving it in water in which the hydrocarbons are insoluble.

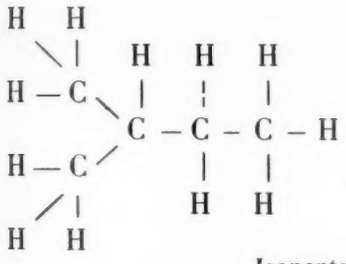
Isomers

Natural gasoline has been treated as if it were a single commodity. However, with the development of the petroleum industry considerable progress has been made in the utilization of some of its individual constituents. For instance, natural gasoline contains certain quantites of a hydrocarbon known as isopentane which is a valuable component of high-grade gasolines. Molecules of normal pentane and isopentane are composed of equal numbers of carbon and hydrogen atoms, but the difference between the two hydrocarbons may be seen from the following pictorial representation of their chemical structure:



or n-C_5H_{12}

Normal Pentane



or iso-C_5H_{12}

Isopentane

Substances consisting of the same number and kind of atoms but differing in structure arrangement are called "isomers." Isopentane is thus an isomer of normal pentane. Commercially isopentane is isolated from natural gasoline by careful fractionation. For other processes, such as for preparation of certain chemicals, a mixture of normal and isopentane may be satisfactory. This shows that the present tendency of the petroleum industry is to utilize the individual compounds present in the gasoline to the fullest extent if their separation is possible and practical.

Commercial Uses of Methane

After removing propanes and heavier hydrocarbons, the remainder of the natural gas consists of methane with a small admixture of ethane. Little commercial use has been found for either of these hydrocarbons except as fuel. Natural gas is used for household heating purposes in and near the California, East Texas, and Louisiana fields. Such utilization depends on the proximity of large towns or factories to the oil fields, which is not usual. Recently pipe lines have been laid to make natural gas available to other distant parts of the country, such as Pennsylvania and New York. The "Big Inch" line built during the war for transporting oil to the East has been converted to carry natural gas. However, a considerable portion of the gas produced with the crude oil, as gas only, is returned to the ground in order to maintain pressure in the oil fields, or is burned to prevent a possible fire hazard such as follow if the gas is released to the atmosphere. The latter practice is now being gradually discontinued. Use of natural gas to maintain pressure in oil-producing fields is also referred to as "repressuring."

More than ten trillion cubic feet of gas is produced annually. This quantity would be sufficient to envelope the state of Rhode Island with a blanket 300 feet deep or, on burning, to produce enough heat to melt and turn into steam a frozen lake occupying 100 acres and 30 feet deep. Eighty per cent of this gas is marketed.

Considerable research has been devoted to commercial utilization of methane, but up to now all efforts in this direction have met with a limited success. The largest quantity of methane is consumed by the carbon black industry, its use as fuel excepted.

Carbon black is an important commodity. It is consumed in quantities of 1½ billion pounds a year. The greatest use of carbon black is as a reinforcing agent in tires and other rubber products. Synthetic rubbers are just as dependent on carbon black as the natural rubbers to make them usable. Carbon black is also used widely in the manufacture of printing inks, phonograph records, paints, polishes, carbon paper, tarpaulins, black tiles, insulating materials, crucible steel and pyrotechnics.

Carbon black is made in many different grades that vary widely in their properties and are not interchangeable. It may contain from 0.3 to 11 per cent oxygen, 0.1 to one per cent hydrogen and up to one per cent ash. The carbon content varies from 88 to 99.5 per cent.

More than half of carbon black is made from natural gas, i.e. methane, by the "channel" process. Smoky flames from thousands of small jets of natural gas are played against a cool iron surface where the smoke, i.e. the minute particles of carbon suspended in the air, condenses. The carbon deposits are scraped off and packaged.

Not all carbon black is prepared by this method. Some of it is made by burning liquid petroleum fractions, including gas oil, in the presence of insufficient quantities of air. Carbon black is also obtained by decomposing hydrocarbon vapors in the absence of air by contacting the gases or vaporized hydrocarbons with the extremely hot brick walls. All these processes produce different carbon blacks that cannot be always graded by the size of the carbon particles of which they are made. Adhesion of these particles to the materials into which they are blended is of much importance. Carbons vary widely in their properties although they may look alike to an uninitiated observer.

In general, preparation of carbon black is a wasteful process. The quantity of carbon recovered is sometimes as low as one per cent and seldom over 3 or 4 per cent of the total carbon present in the burned gas. One thousand feet of methane produces from ½ to 1½ lb of carbon black, which is very little when compared to the maximum theoretical recovery of over 30 lb. This not as wasteful as it may look at the first glance. In Texas, for example, natural gas often contains much sulfur and cannot be sold as fuel by sending it through the regular pipe lines as "line gas." Its most efficient utilization is by burning it into carbon black.

Methane is also employed for the manufacture of hydrogen. This is done by heating it to very high temperatures at which it decomposes into carbon and hydrogen. Hydrogen thus produced is used by some of the petroleum hydrogenation processes that are described later and which increase the quantity of products recoverable from a barrel of crude oil. Attempts have been made to utilize methane for preparation of chemicals, such as acetylene, but the expense involved and the limited use of the resulting prod-

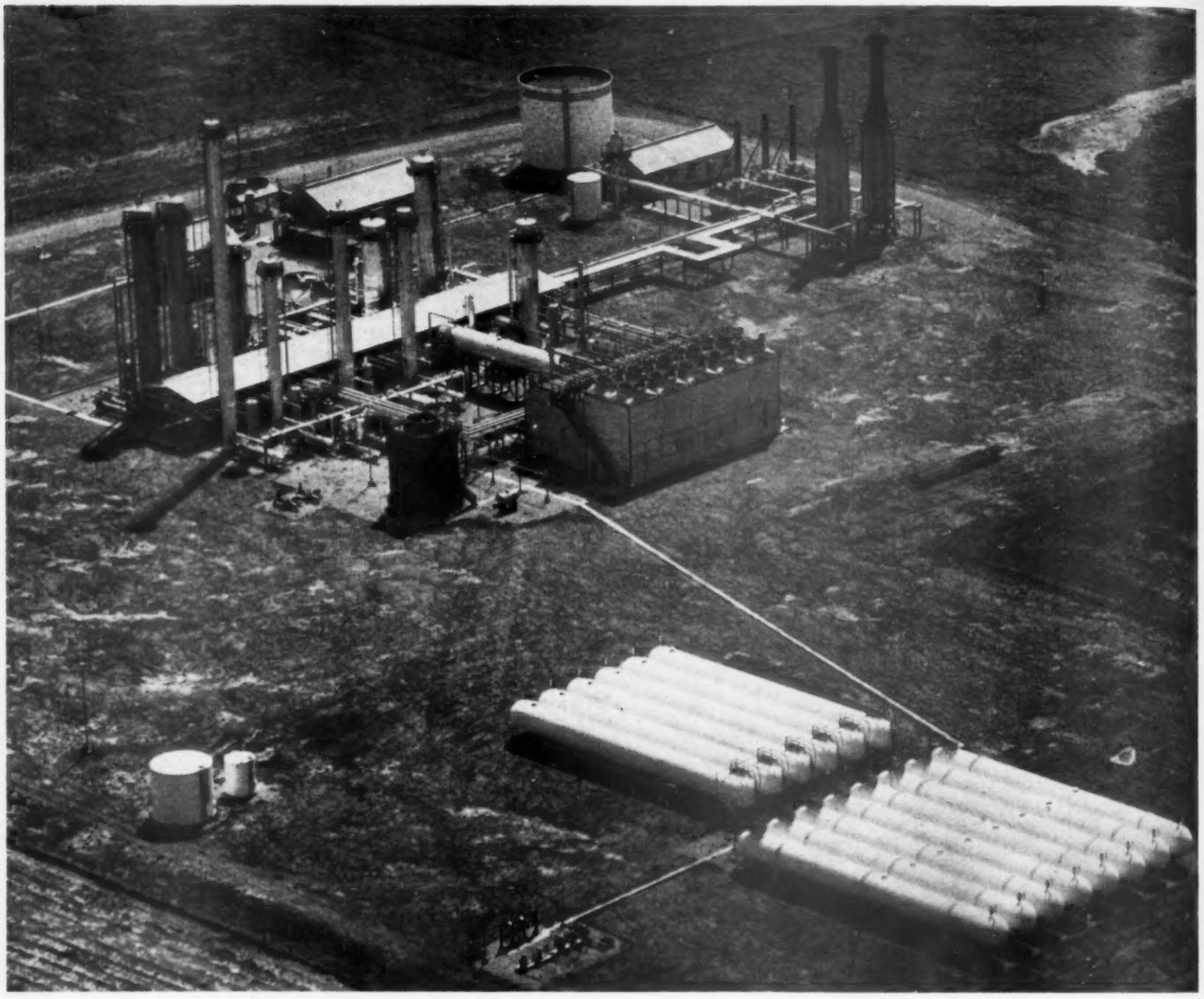


FIG. 6. Outstanding example of an ultra-modern (1955) natural gasoline plant, showing pressure storage — horizontal tanks in foreground — for light liquids.

ucts has retarded development of such processes up to the present.

Helium

Helium is recovered from natural gas if the content is sufficiently high to warrant it. In Amarillo, Texas, recovery is made by the use of very low temperatures. Helium is the last substance to liquefy, as it boils at temperatures considerably below those required for atmospheric and all other gases. This is shown in Table 4 C.

TABLE 4C. Boiling and melting points of common gases.

Gas	Boiling point, °F	Melting point, °F
Helium	—452	—458 (a)
Hydrogen	—423	—435
Nitrogen	—320	—346
Oxygen	—297	—361
Methane	—259	—299
Ethane	—127	—278

(a) At a pressure of 382 psi (26 atmospheres).

(a) At a pressure of 382 psi (26 atmospheres). The theoretical absolute zero, which is the lowest temperature that can exist according to science, is 459.4 F. (—273.13 C).

Natural gas containing helium is cooled under pressure until all its components liquefy or freeze with the exception of helium. Helium is then easily separated as a gas from the liquid-solid mixture.

As yet helium has found few commercial uses. Originally it was expected that it might be a very effective substitute for hydrogen in filling dirigibles and other aircraft lighter than air. Helium is very light and closely approaches hydrogen in lifting power. Contrary to hydrogen, it is not inflammable and belongs to the so-called "noble" group of gases that are inert chemically, forming no known combinations with other elements. The unfortunate happenings with the dirigibles shortly before the last war and the tremendous progress of the airplanes reduced practically to zero the possibilty of employing large quantities of helium for this purpose. New uses for it may be developed, as indicated by the recent success in employing helium for special welding processes or in relieving asthma patients by feeding them with a mixture of helium and oxygen. Such a mixture is also used by deep-sea divers to overcome harmful effects of nitrogen in the air under high pressure, that is, to prevent "the bends."

Helium reserves in this country are estimated at six billion cubic feet. This large quantity justifies a considerable amount of research connected with its utilization, and the future may hold some new and unexpected uses for this gas which was considered a curiosity not many years ago. First discovered by spectroscope in 1868 in the sun's atmosphere, helium was worth $2500 per cubic foot in 1917. It is now sold for 50 cents per cubic foot.

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POWELL VALVES FOR MODERN INDUSTRY

FIG. 2193—Ni-Resist* Gate Valve for 200 Pounds W.O.G.

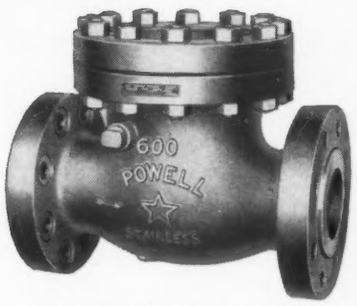
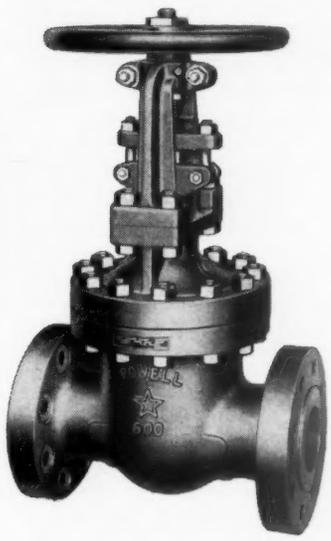


FIG. 6061 SS—600 Pound Stainless Steel Swing Check Valve

FIG. 6003 SS—Alloy Steel Gate Valve for 600 Pounds W.S.P.



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Motion Picture Study Shows Difference Between Tray Designs

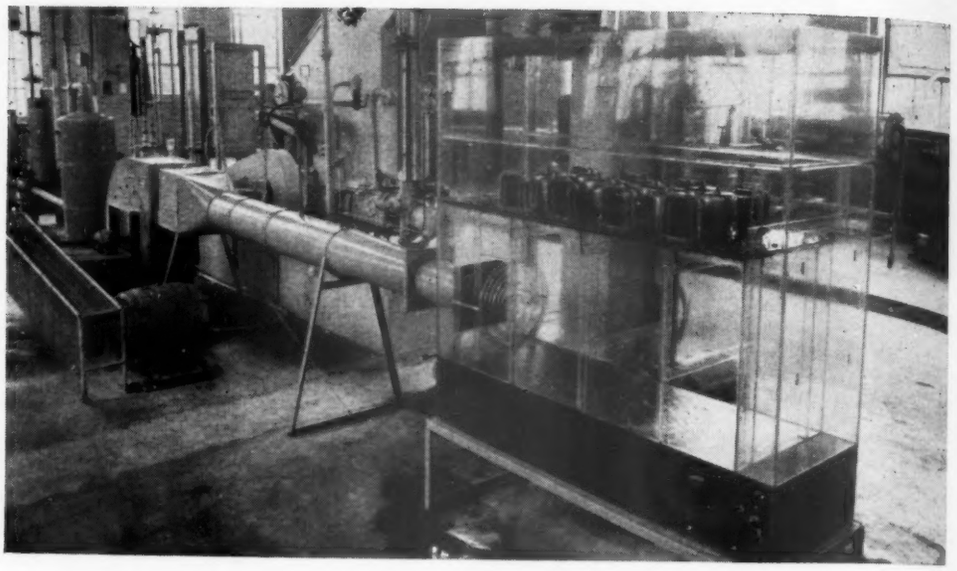


FIG. 1. Experimental assembly with bubble tray in place.

Hydraulics of Gas-Liquid Contacting Trays

W. E. Brook, D. E. Honnold,
W. C. Cunningham, R. L. Huntington*
University of Oklahoma, School of Chemical Engineering

SINCE 1924 the bubble-cap tray has held a leading place as a gas-liquid contacting device for fractionators and absorbers in the petroleum industry. From time to time designers have come forth with various types of contactors that have shown some promise of making substantial inroads on the conventional bubble-cap tray due primarily to the possibility of cheaper construction or to the attainment of higher efficiencies. But to date no device has been found that will equal the vapor-load flexibility of the variable orifice that the vertical slots of the bubble tray so uniquely provide.

Importance of Visual Studies

Before World War II improvements in tray design came about largely through the expensive trial-and-error route. Since 1945 there has been an increasing interest in visual studies as a means of obtaining a clearer insight into the nature of tray hydraulics. The current availability of strong transparent plastic and glass plates and piping, as well as of better photographic equipment have made these visual studies possible.[1a, 2, 5, 6, 8]

Experimental Apparatus

In order to come closer to the simulation of a commercial tower, a clear rectangular plexiglas box was recently assembled in our laboratories, as shown in Fig. 1. It has a built-in downspout and auxiliary equipment for supplying air and liquid to the single tray, which is readily removable overhead. The cement used in the fabrication of this box consisted of a solution of Tenite shavings in ethylene dichloride.

The overall dimensions of this plastic box are: Width, 15 in.; length, 48 in.; and height, 48 in.—with a 14½-in. by 39½-in. tray located on an internal flanged rim 28 in. from the bottom. The tray itself has an active area of 12 in. by 37 in. The box represents a rectangular section of a cylindrical tower 4 ft in diameter, over which liquid flows lengthwise. With practically 100 per cent visibility through the sides and ends of the box, it is possible to observe very closely such details as:

1. Percentage of the tray which is active at any time.
2. Bubbling action and froth heights across the length of the tray, as well as the froth height in the downspout.
3. Liquid gradient across the tray.
4. Pressure drop through the plate.
5. Entrainment is obtained by sampling a portion of the cross-section at the top of the box. The top is covered with a 1-in. layer of wire mesh, except for the improvised 6-in.-inside-diameter entrainment bell-cap device in the

*School of Chemical Engineering, University of Oklahoma, Norman, Oklahoma. *Note:* Brook is a graduate student and Gulf Oil Corporation fellow; Honnold is an undergraduate student and holds a Maloney-Crawford Tank and Manufacturing Company scholarship: Cunningham is an undergraduate student and holds a Universal Oil Products Company scholarship; and Huntington is professor of chemical engineering.

†Presented by Dr. Huntington, to a session on fractionation during the 19th Mid-Year Meeting of the American Petroleum Institute's Division of Refining, in the Rice Hotel, Houston, Texas; presiding, T. W. Nelson, Socony-Vacuum Oil Company, Inc., New York.

TABLE 1. A. Physical Properties of Liquids.

I. Surface tension (dynes per centimeter):

Temperature (Deg F)	Water: Surface Tension	Diethylene Glycol: New (Deg F)	Diethylene Glycol: Used (Deg F)	Gas Oil: New (Deg F)	Gas Oil: Used (Deg F)
68	72.8	92 44.3	74 49.0	66 27.6	77 27.8
		119 42.7	117 46.75	88 26.2	88 27.2
				113 25.4	93 26.7
					128 25.4

II. Density:

Water: 1 gram per ml at 60 F

Diethylene Glycol: 1.123 grams per ml at 84 F; 1.104 grams per ml at 119 F

Gas Oil: 0.84 gram per ml at 60 F

III. Viscosity (centipoises):

Water: 1.0 at 70 F

Diethylene Glycol: New—24.9 at 85 F; Used—25.6 at 75 F

Gas Oil: New—3.0 at 73 F; Used—3.3 at 73 F

B. Time Required for Drainage of Tray.

I. Liquid depth at start: 2.5 in.

Tray	Gas Oil: Temperature (Deg F)	Gas Oil: Seconds	Diethylene Glycol: Temperature (Deg F)	Diethylene Glycol: Seconds
Bubble cap*	88	600	95	720
Perforated	85	28	85	50
Nutter	97	90	90	360
Koch	85	85	90	120

* One ¼-in. weephole.

Appendix "A", Froth-Height Data.

Glitsch Bubble-Cap Tray

Liquid	Gallons per minute	Air (pounds per hour per square foot)	Froth height on tray (inches)	Downspout froth height (inches)	Calculated froth density (grams per cubic centimeter)
Water	40	217	5.5	2.25	0.845
	40	535	9.0	3.25	0.830
	78	172	6.0	2.50	1.02
	78	644	11.0	4.00	0.85
Glycol	40	170	6.0	2.00	1.09
	40	593	11.0	2.75	1.03
	78	279	8.0	3.00	0.97
	78	665	13.0	3.50	1.09
Gas oil	41	209	8.0	5.00	0.30
	41	604	14.0	8.00	0.28
	82	208	8.0	4.50	0.42
	82	532	14.0	5.50	0.46

Celanese Perforated

Liquid	Gallons per minute	Air (pounds per hour per square foot)	Froth height on tray (inches)	Downspout froth height (inches)	Calculated froth density (grams per cubic centimeter)
Water	40	310	5.5	4.00	0.88
	40	870	8.0	8.25	0.93
	78	264	6.0	4.00	0.92
	78	871	8.5	8.00	1.01
Glycol	40	205	5.5	3.50	1.03
	40	818	9.0	7.75	0.99
	78	266	6.5	4.00	1.00
	78	806	9.0	8.00	1.00
Gas oil	41	169	6.0	24.00	0.09
	41	827	12.0	25.00	0.29
	82	196	7.0	9.50	0.28
	82	752	13.0	23.50	0.27

Koch Flipper Tray

Liquid	Gallons per minute	Air (pounds per hour per square foot)	Froth height on tray (inches)	Downspout froth height (inches)	Calculated froth density (grams per cubic centimeter)
Water	40	262	6.0	3.75	0.96
	40	1,012	9.5	7.25	0.96
	78	279	6.5	4.50	0.92
	78	974	10.0	7.50	0.97
Glycol	40	197	6.0	3.75	0.89
	40	940	11.0	6.26	1.10
	78	295	8.0	4.50	1.20
	78	914	12.0	6.50	0.99
Gas oil	41	220	8.0	14.0	0.16
	41	790	12.0	22.0	0.18
	82	261	8.0	9.0	0.29
	82	736	12.0	12.5	0.30

Nutter Float-Valve Tray

Liquid	Gallons per minute	Air (pounds per hour per square foot)	Froth height on tray (inches)	Downspout froth height (inches)	Calculated froth density (grams per cubic centimeter)
Water	40	220	5.5	3.75	0.88
	40	1,043	10.0	7.00	0.85
	78	260	6.5	4.00	1.00
	78	1,008	10.0	7.50	0.84
Glycol	40	260	5.5	3.75	0.96
	40	1,017	10.0	5.75	0.87
	78	220	6.5	4.00	1.17
	78	967	12.0	6.00	0.96
Gas oil	41	274	7.0	23.00	0.12
	41	877	13.0	23.00	0.21
	82	205	7.5	12.50	0.25
	82	672	12.0	15.00	0.28

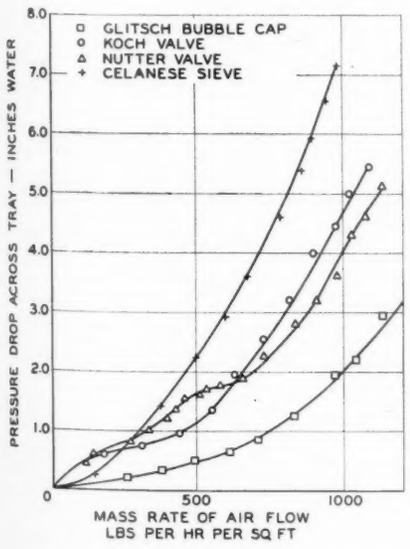


FIG. 2. Pressure drop vs. mass rate of air flow—no liquid flow.

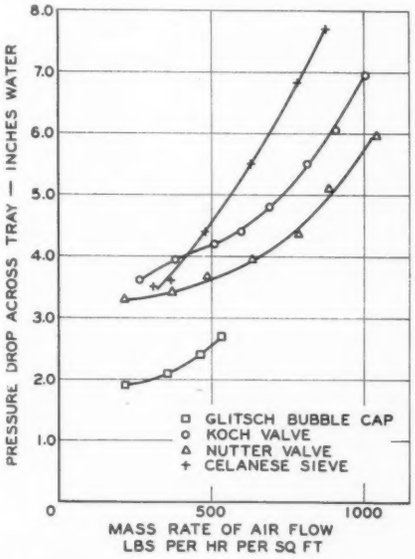


FIG. 3. Pressure drop vs. mass rate of air flow; 40 gpm water flow rate.

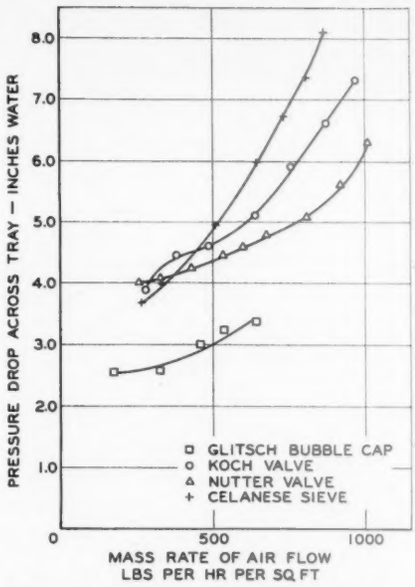


FIG. 4. Pressure drop vs. mass rate of air flow; 78 gpm water flow rate.

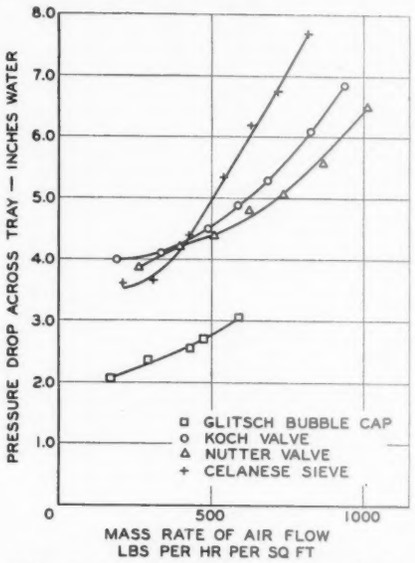


FIG. 5. Pressure drop vs. mass air flow rate; 40 gpm diethylene glycol flow rate.

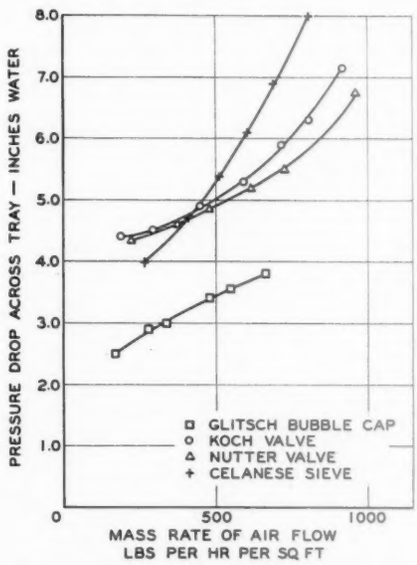


FIG. 6. Pressure drop vs. mass air flow rate; 78 gpm diethylene glycol flow rate.

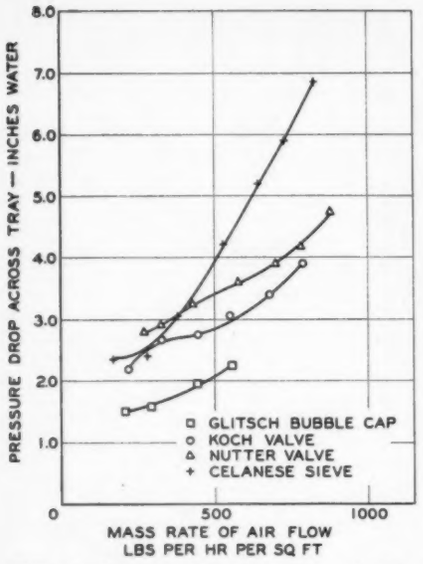


FIG. 7. Pressure drop vs. mass air flow rate; 41 gpm gas oil flow rate.

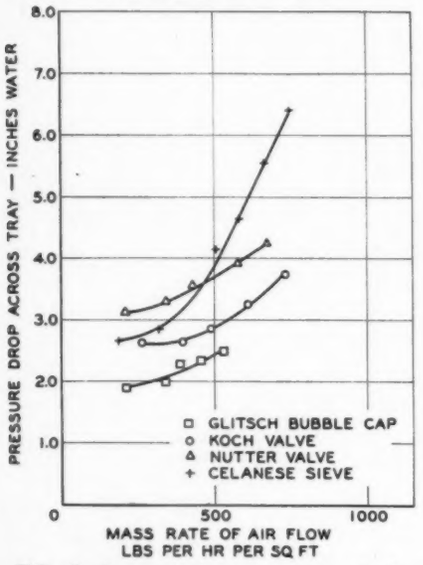


FIG. 8. Pressure drop vs. mass air flow rate; 82 gpm gas oil flow rate.

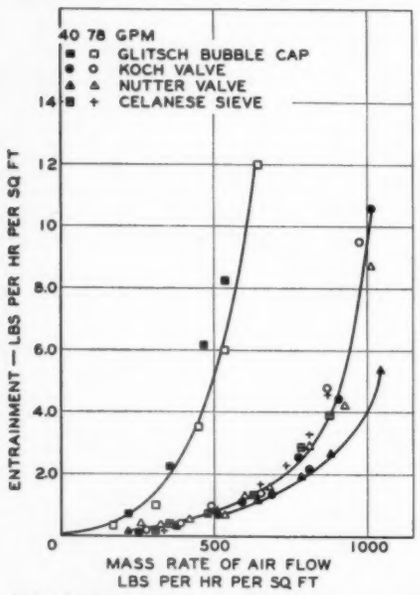


FIG. 9. Entrainment vs. mass air flow rate; 40 gpm and 78 gpm water flow rates.

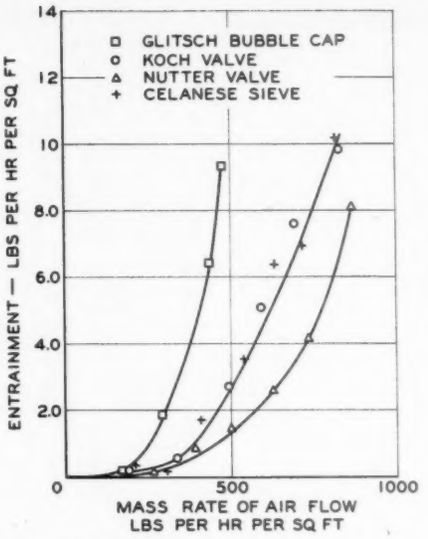

GLITSCH BUBBLE CAP
KOCH VALVE
NUTTER VALVE
CELANESE SIEVE
ENTRAINMENT — LBS PER HR PER SQ FT
MASS RATE OF AIR FLOW
LBS PER HR PER SQ FT

FIG. 10. Entrainment vs. mass air flow rate; diethylene glycol flow rates of 40 gpm.

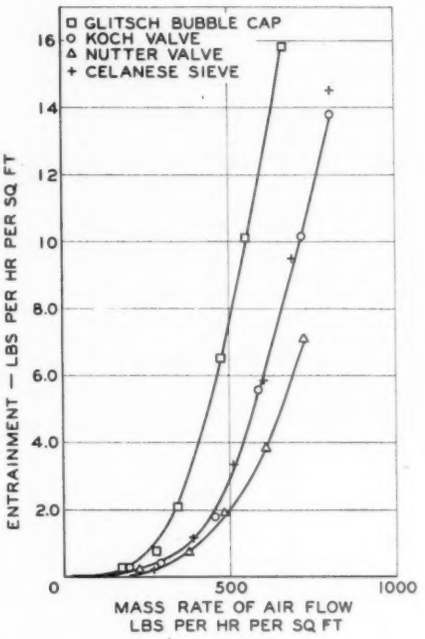

GLITSCH BUBBLE CAP
KOCH VALVE
NUTTER VALVE
CELANESE SIEVE
ENTRAINMENT — LBS PER HR PER SQ FT
MASS RATE OF AIR FLOW
LBS PER HR PER SQ FT

FIG. 11. Entrainment vs. mass air flow rate; diethylene glycol flow rate of 78 gpm.

center. Distance from tray to entrainment trap is 19 in.

6. Air and liquid flow rates through and across the plate, respectively.

Three general types of plates have been studied to date in this investigation—with air used as the gas, and with water, diethylene glycol, and a gas oil with an API gravity of 37 deg as the liquids.

The experimental trays that were studied are as follows:

1. One bubble tray by Glitsch and Sons, Dallas, Texas.

2. Perforated tray, by Celanese Corporation, 3/16-in. holes with ¾-in. triangular spacing.

3. Two valve-plate trays.
   a. Koch Engineering Company, Wichita: round valves.
   b. Nutter Engineering Company, Amarillo, rectangular valves.

Construction details of the trays are shown in Appendix "A."

Physical properties of the 3 liquids, as well as the time required for tray drainage, are presented in Table 1.

Experimental Results

Motion-Picture Studies. Both normal and slow-motion pictures have been made of the several plates operat-

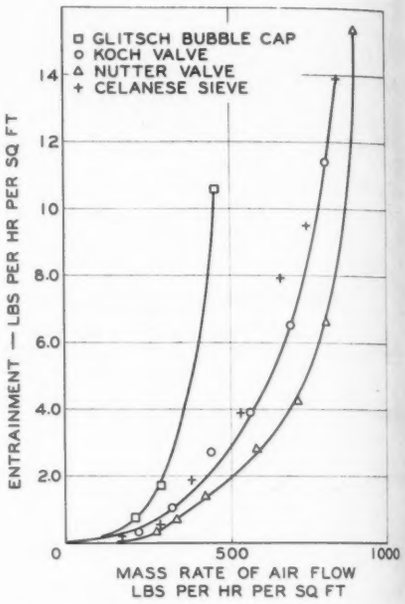

GLITSCH BUBBLE CAP
KOCH VALVE
NUTTER VALVE
CELANESE SIEVE
ENTRAINMENT — LBS PER HR PER SQ FT
MASS RATE OF AIR FLOW
LBS PER HR PER SQ FT

FIG. 12. Entrainment vs. mass air flow rate; 41 gpm gas oil flow rate.

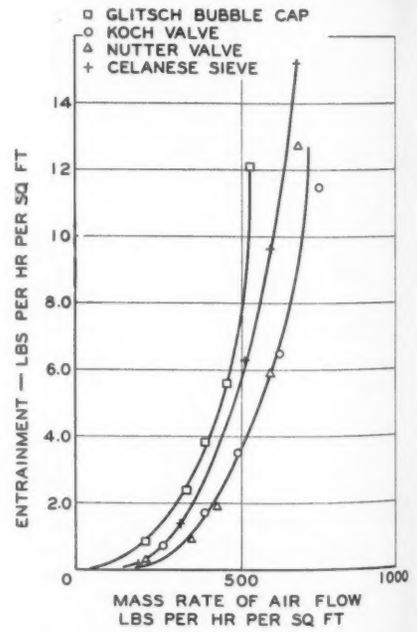
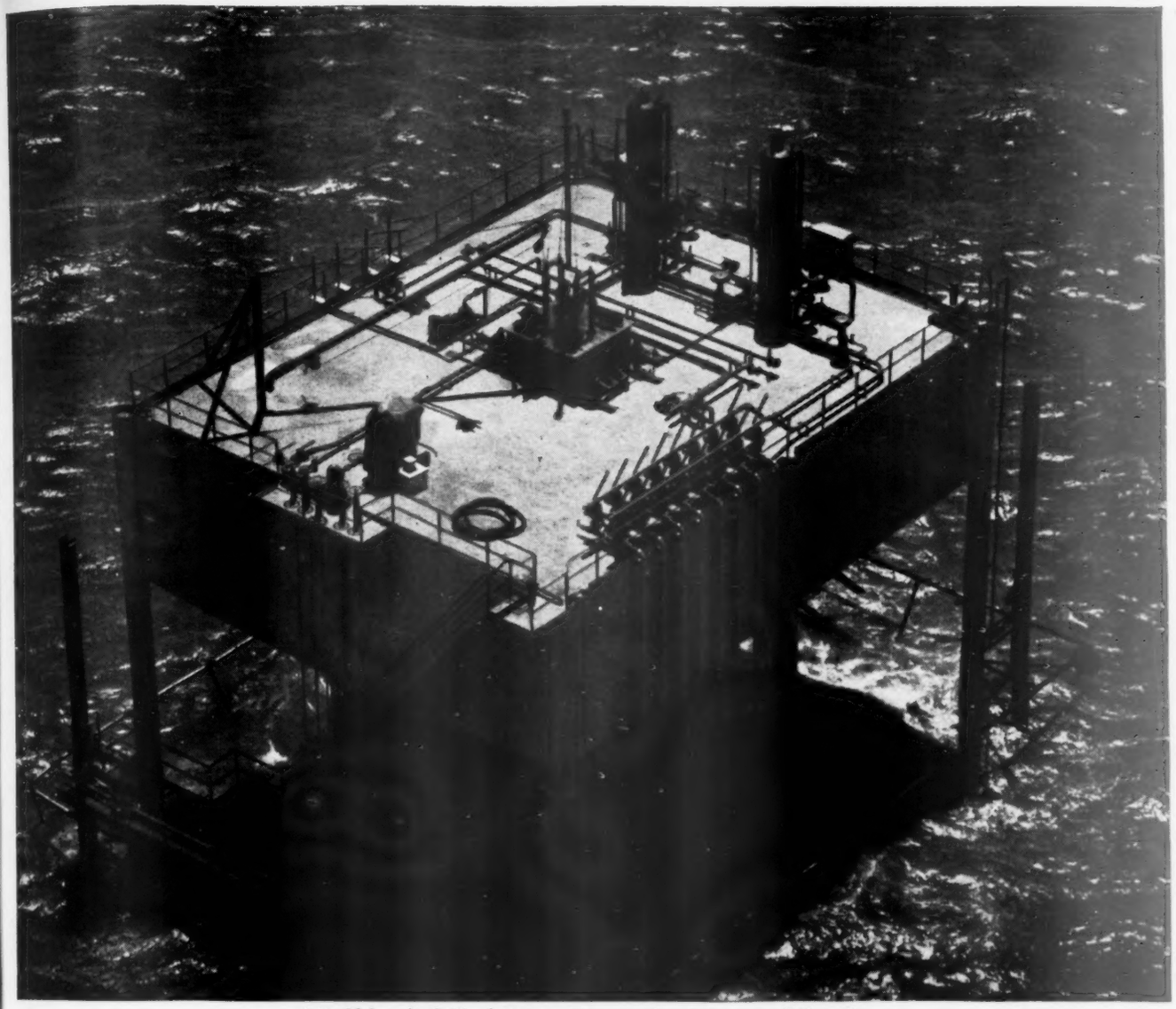

GLITSCH BUBBLE CAP
KOCH VALVE
NUTTER VALVE
CELANESE SIEVE
ENTRAINMENT — LBS PER HR PER SQ FT
MASS RATE OF AIR FLOW
LBS PER HR PER SQ FT

FIG. 13. Entrainment vs. mass air flow rate; 82 gpm gas oil flow rate.



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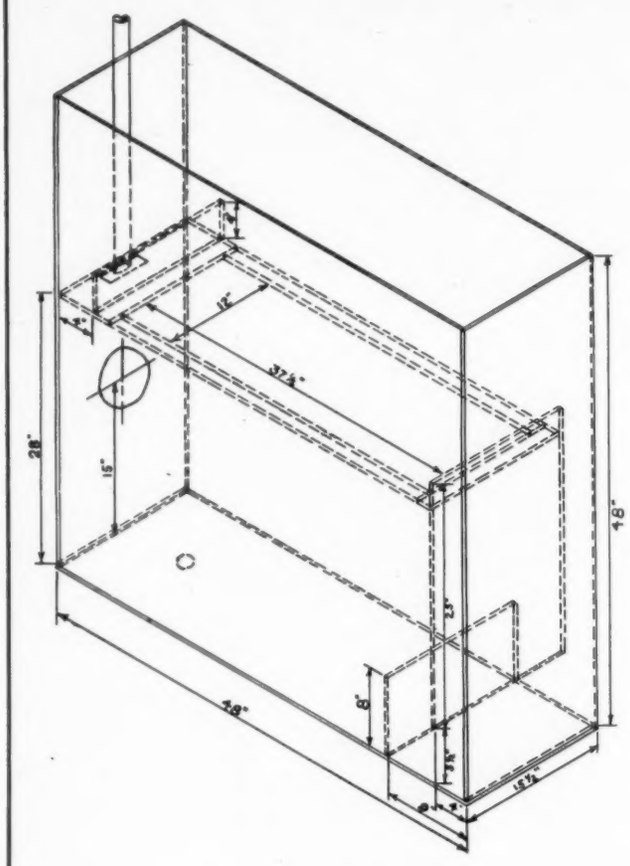

FIG. 14. Experimental plastic tower.

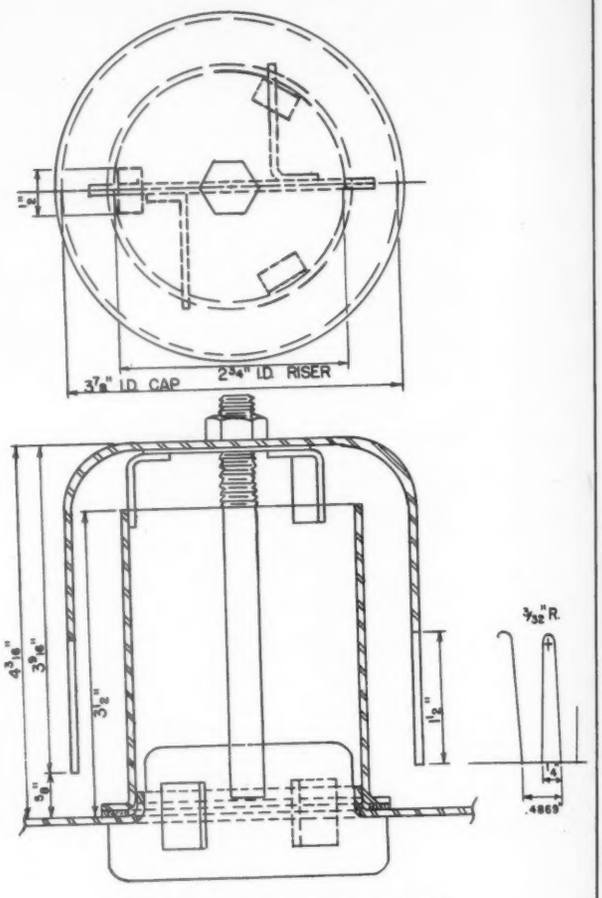

FIG. 15. Details of Glitsch bubble cap.

ing under various gas-liquid ratios and flow rates. These pictures have been taken at night with type "A" Kodachrome 16-mm film under a floodlight intensity of 25 on a Weston meter. The film is a silent one; however, explanatory scrip precedes each set of flowing conditions.

Tray-Action Characteristics

Under the range of flow rates studied in this investigation, it is possible to make a few generalizations—based on visual observations in regard to the nature of the bubbling action and froth formation—for the several trays, respectively.

This summary does not adequately describe the tray hydraulics; however, for the benefit of those designers who do not have the opportunity of seeing the motion picture film, it is felt that a word picture may provide some worthwhile information.

a. Froth formation: The densest and most persistent froth was formed with gas oil, at high gas-liquid ratios with the perforated plate and the least froth with the bubble-cap tray. See Appendix "A" for froth data.

b. The perforated plate was active over a higher percentage of its area for low air rates; however, this advantage was gained at the expense of a larger pressure drop through the tray. At low air rates the bubble-cap tray had the lowest percentage of active area.

c. At high liquid and moderate air rates the bubble-cap tray looked like a turbulent sea, with active spots shifting back and forth. The perforated trays did not display this type of "hunting" action, but the valve trays did to a moderate extent.

d. Drainage time upon shutdown was the quickest for the perforated plate, and slowest for the bubble tray which had only one weephole.

Pressure Drop vs Flow Rates

Huitt et al.[4] have reported results on the pressure drop through bubble caps. In this study only the overall pressure drop through the tray has been observed on each run, and these results are presented graphically in Fig. 2 through 8. The pressure drop is largely a function of gas-flow rate. The bubble-cap tray encountered the small-

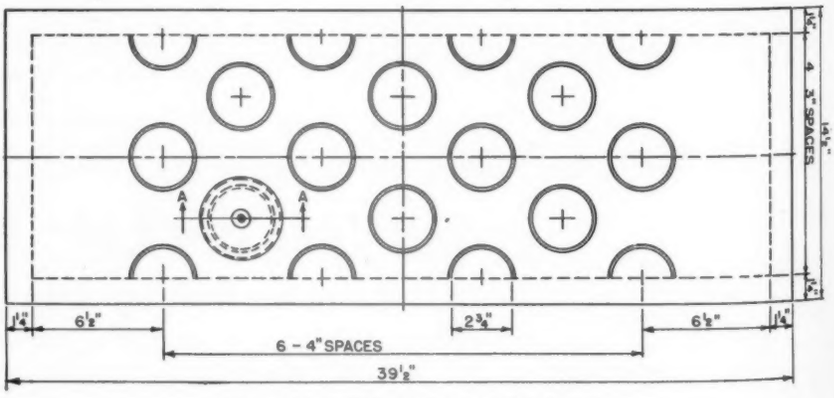

FIG. 16. Details of Glitsch bubble tray.

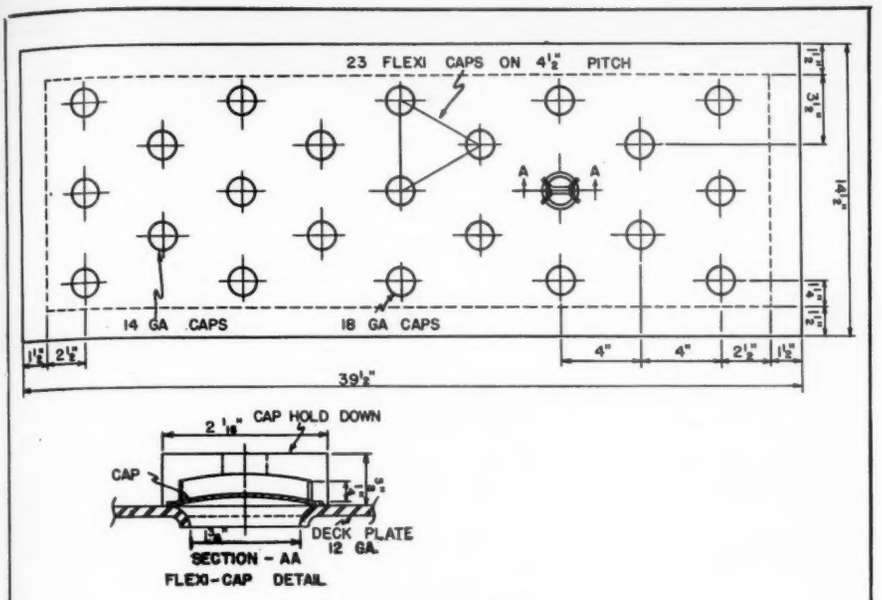

FIG. 17. Koch Flexi-tray.

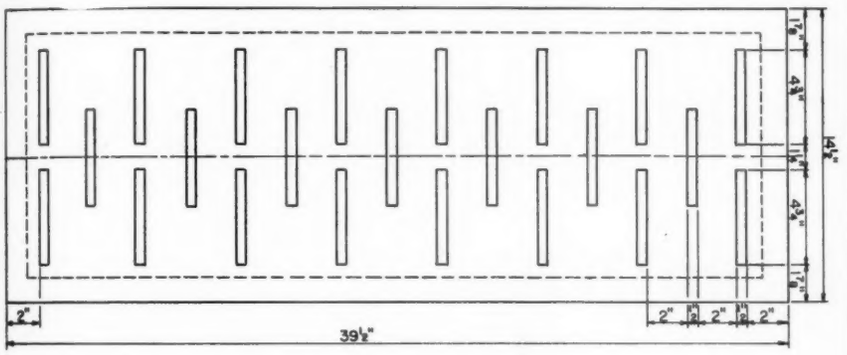

FIG. 18. Nutter float-valve tray.

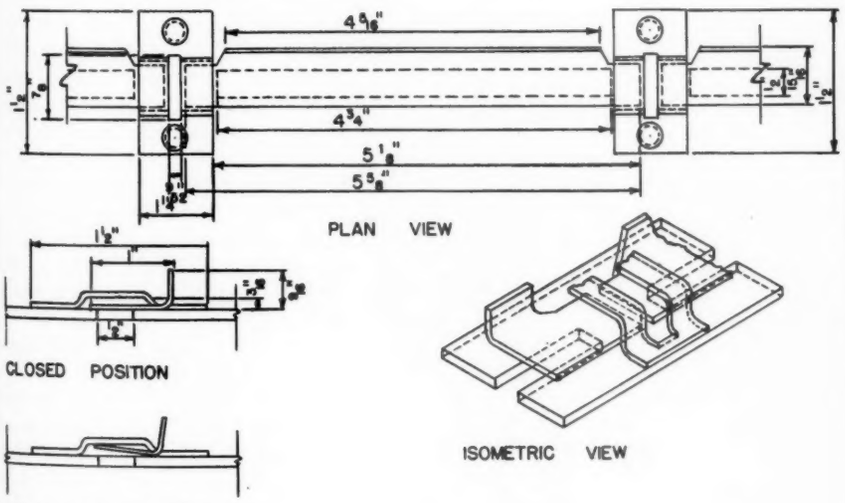

FIG. 19. Details of Nutter float-valve assembly.

est drop in pressure, followed in succession by the valve plate and perforated tray. Mass rates of air flow are based on open tower area.

Entrainment

Entrainment, or the mechanical carrying of liquid droplets from one tray to another, is frequently referred to as one of the important factors in tower design. A deterrent to the attainment of high efficiency, entrainment should be minimized; however, economic considerations prevent its complete elimination from a practical standpoint. Souders et al.[7] and Eld[3] have related tower design to entrainment.

In this investigation various experimental methods of determining entrainment were considered; however, only one was used in obtaining the carryover from the active plate, viz., the gravimetric measurement of the liquid accumulated in the plastic-cap trap located in the center of the wire-mesh cover mat.

The results of these measurements show that entrainment is largely a function of vapor velocity and the surface tension of the liquid being processed (Fig. 9 through 13).

Conclusion

The authors wish to make it clear that the complete performance characteristics of the several trays reported in this study cannot be defined because of the limited range of air and liquid loads under which they were tested.

Results will be reported in the near future on the performance of a perforated tray designed by Gulf Oil Corporation's refinery division.

Acknowledgment

The authors wish to express their appreciation for the financial assistance that the following companies have so generously provided in connection with this investigation: 1. Gulf Oil Corporation, Pittsburgh, Pennsylvania; 2. Maloney-Crawford Tank and Manufacturing Company, Tulsa, Oklahoma; and, 3. Universal Oil Products Company, Chicago, Illinois.

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[1] C. F. Braun and Company, Alhambra, California; bubble-tray motion picture.
[2] E. I. du Pont de Nemours and Company, Inc.: formation.
[3] A. C. Eld, "A New Approach to Tray Design," *Petroleum Refiner*, 32 [5] 157 (1953).
[4] J. L. Huitt and R. L. Huntington, "Pressure Drop Through Bubble Caps," Part I—Introduction, *Petroleum Refiner*, 30 [6] 131; Part II—Equipment 30 [8] 111; Part III—Application of Theoretical Equations [30] 153 (1951).
[5] The M. W. Kellogg Company, New York, N. Y.: bubble-tray motion picture.
[6] Shell Development Company: bubble and turbo-grib motion pictures.
[7] M. Souders, Jr., and G. G. Brown, "Design of Fractionating Columns: I — Entrainment and Capacity" *Ind. Eng. Chem.* 26, 98-103 (1934).
[8] Standard Oil Development Company, Linden, New Jersey: bubble-cap test plate. * *

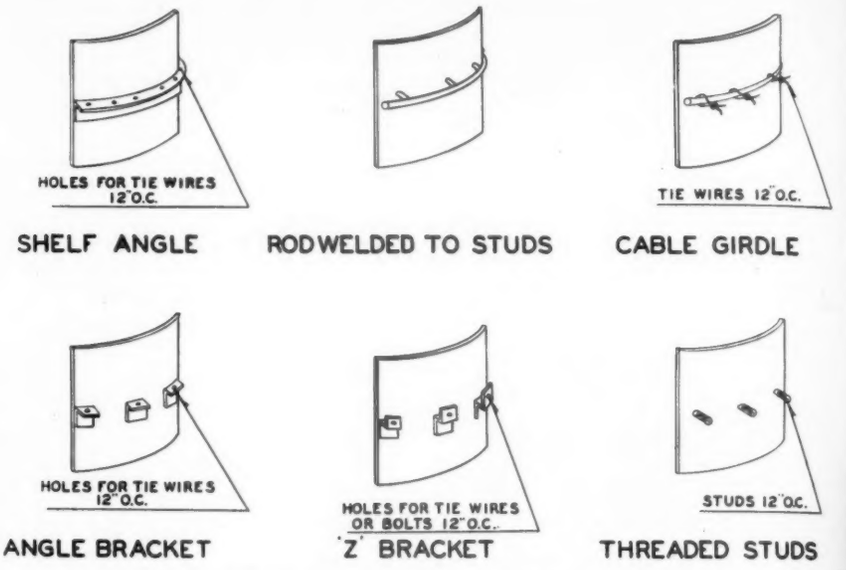


FIG. 1. Different supports for insulation and metal sheets.

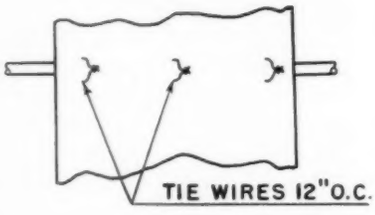
METAL INSULATION JACKETS PROVIDE WEATHER PROTECTION

Harold L. Humes
Baldwin-Hill Co.

AN applicator's success in insulating high-temperature surfaces on cylindrical vessels located outdoors depends greatly on the effectiveness of the method used to protect the insulating materials from weather. The development of improved weatherproofing techniques and materials has provided a long service life, at high insulating efficiency and with minimum repair.

Aluminum and galvanized steel, either corrugated or plain, are being used increasingly to protect the insulation on cylindrical vessels. They provide both excellent protection and a bright, clean appearance. Correctly designed sheet-metal jackets not only protect the insulation from the weather, but also permit the circulation of air through the metal joints.

The "Manual for Industrial Insulation Specifications" prepared by the Baldwin-Hill Company, Trenton, New Jersey, manufacturers of spun mineral wool Mono-Block and blanket insulation, describes several methods of attaching sheet-metal weather proofing on cylindrical vessels. These methods, or special adaptations to fit specific requirements, will provide a tight weather barrier and an excellent appearance. The particular method chosen



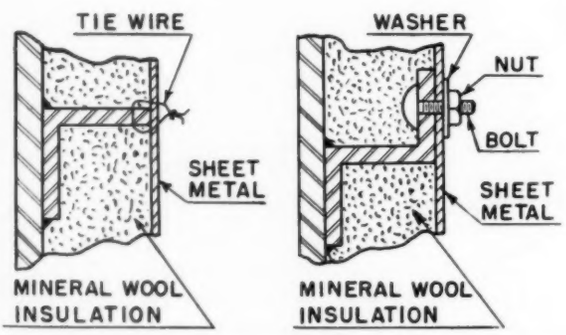
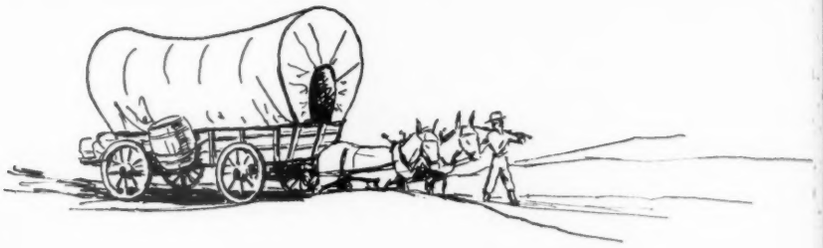


FIG. 2. Metal sheets may be fastened to supporting members by any of these methods.

EXCLUSIVE

LEADING THE WAY



As they traveled through unfamiliar regions in their prairie schooners, the pioneer settlers of the western regions of America were faced with many uncertainties. For them, the journey was truly a voyage into the unknown.

Innumerable doubts and misgivings can be present, too, when you embark on an important expansion program, particularly when a decision must be reached on the selection of a process construction organization. There can be no turning back after the commitment becomes final.

You will be free of this concern when you choose Procon, with its complete design, engineering, and construction facilities. Procon has repeatedly demonstrated its leadership in completing a wide variety of projects according to the specified requirements.

Our engineering staff can show you in detail why your next process construction job should be handled by Procon.

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WORLD-WIDE CONSTRUCTION FOR THE PETROLEUM, PETROCHEMICAL, AND CHEMICAL INDUSTRIES

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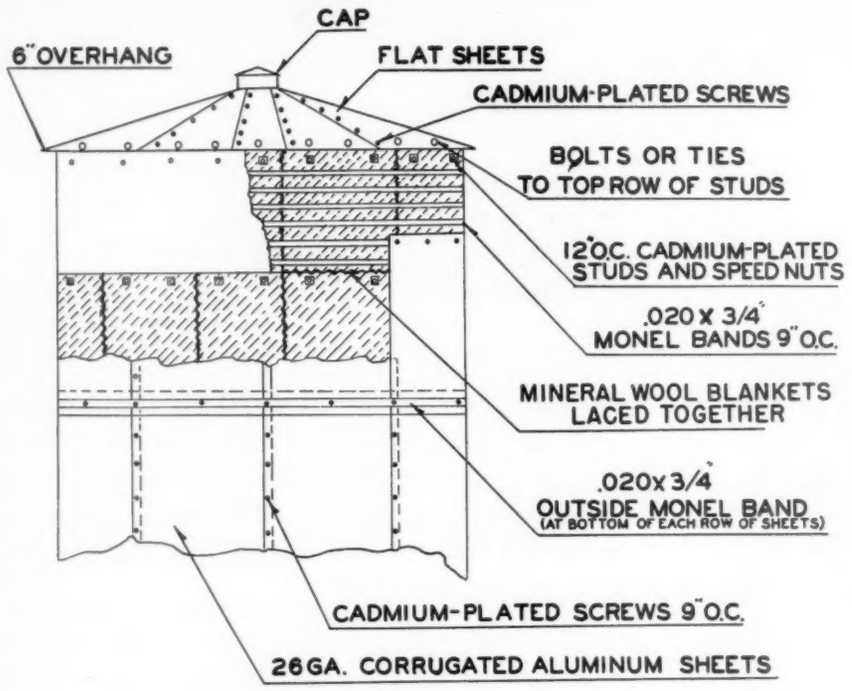
CAP
6" OVERHANG
FLAT SHEETS
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BOLTS OR TIES TO TOP ROW OF STUDS
12" O.C. CADMIUM-PLATED STUDS AND SPEED NUTS
.020 X 3/4" MONEL BANDS 9" O.C.
MINERAL WOOL BLANKETS LACED TOGETHER
.020 X 3/4" OUTSIDE MONEL BAND (AT BOTTOM OF EACH ROW OF SHEETS)
CADMIUM-PLATED SCREWS 9" O.C.
26 GA. CORRUGATED ALUMINUM SHEETS

◆ FIG. 3. Over blanket-type insulation metal sheets may be fastened in the manner shown here.

depends on such factors as the preference of the specifier or contractor and the materials and tools available to do the job.

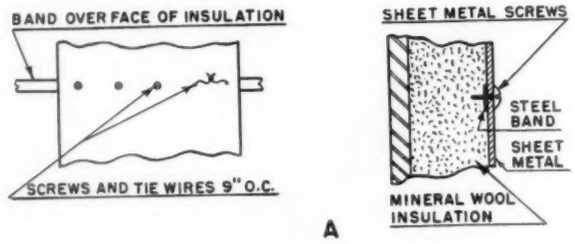
Both mineral wool block and blanket insulation may be used to insulate vessels located outdoors. The insulation thickness will depend on the temperature of the surface and can be determined from Commercial Standard CS 117-49. Block insulation has greater structural strength and may be used to 1700 F. Blocks may be attached to the insulated surface with lagging studs, headless welding pins, or steel-band girdles.

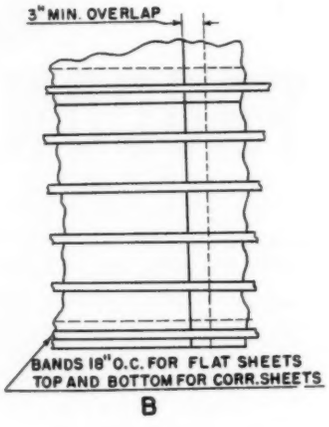
Blankets are more flexible and come in larger sizes, therefore requiring less layout and handling during application. They may be used to insulate surfaces to 1200 F. The recommended methods of attached mineral wool blankets include tie-wires attached to steel-bands, headless welding pins, and outside galvanized steel bands.

CS 117-49 recommends that sheet-metal jackets for mineral wool insulation should be no lighter than No. 28-gage, single or double-galvanized. The metal should be of a type suited to withstand the expected condition of exposure. Fasteners—screws, bolts, washers, bands and wire—should be adapted to intimate contact with the sheets without causing galvanic corrosion arising from the contact of dissimilar metals.

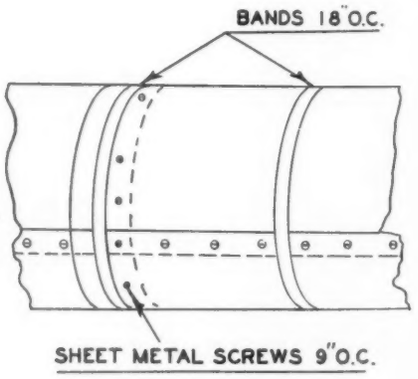
The metal sheet may be fastened to the exterior of the vessel by supports (Fig. 1) that are fastened to the vessel, and extend through the insulation. In Fig. 2 these supports — angle iron shelves, angle lug brackets, or bands, rods, or cables welded, wired, screwed or bolted to brackets or studs—may also be utilized in securing the insulation, and should be spaced to suit the dimensions of the metal sheets.

If lightweight sheets are used over blanket-type insulation they may be attached by screws or tie-wires to bands





◆ FIG. 4. A. Lightweight sheets may be secured by either system. B. Weather-proofing sheets are held in place by circumferential bands.



◆ FIG. 5. Flat sheets on horizontal tanks are fastened by screws.

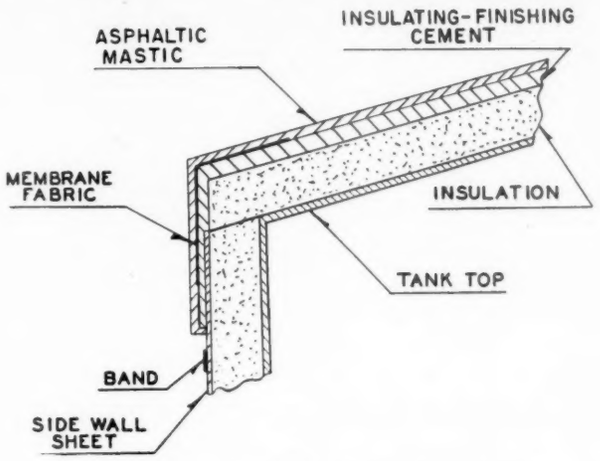


FIG. 6. Special methods are shown here for attaching sheets at tank eaves.

that have been wired to the exposed metal lath face. Fig. 3 is a cutaway drawing of an installation in which the sheets have been attached by screws to metal bands encircling blanket insulation. Fig. 4a illustrates methods of attaching lightweight sheets.

The sheets are applied to the vessel in horizontal courses beginning at the bottom of vertical surfaces. Each horizontal course is completed before the next higher one is begun. The vertical edges of adjacent sheets may be fastened together with sheet-metal screws on nine-inch centers. Subsequent courses of metal sheeting are applied with the bottom edge of the higher course overlapping the top of the one below. These laps at the top and bottom of each course can be designed to coincide with blanket joints. If this is done and the sheets are not joined an expansion joint results. Fig. 4b shows the sheets further secured by the use of circumferential bands applied on the outside of each course approximately six inches above the bottom edge. The tightened bands with their ends sealed together, are anchored by sheet-metal screws extending through both bands and sheets. Additional bands on 18-in. centers should be used to anchor flat uncorrugated sheets.

On horizontal surfaces (Fig. 5), where joints must be weather-tight, use flat metal sheets with lapped seams, soldered laps, or standing seams applied according to standard roofing practice. Bands applied at appropriate intervals will prevent bulging on horizontal surfaces.

The junctions between vertical and sloping or horizontal surfaces must also be protected. Sloping roofs with eaves may be weatherproofed by wedge-shaped sections of metal sheets cut to match the area to be covered (Fig. 1). An overlap of from 3 to 6 in. is necessary at all joints to keep out rain. If possible, long sheets, extending from the center to the edge in one piece, thus eliminating a joint in one direction, should be used. Flashing or plastic caulking over and under the metal sheet will protect joints around man-holes, pipe connections, and other projections.

Lap cement or plastic caulking in the overlaps will protect radial joints. The sheets are fastened to supports arranged in concentric circles near the center and edge and at intermediate intervals on 18 or 24-in. centers. Screws or bolts fasten the sheets and either weatherproof washers are used under the heads, or all the screw heads must be caulked after they are pulled up tight. Overlapping edges are fastened using screws on 9-in. centers. Sufficient overhang must be provided to prevent rain from entering the insulation on the vertical surface.

Fig. 6 illustrates how flat or low-pitched roofs may be weatherproofed with insulating-finishing cement and asphaltic mastic. The cement and the mastic are applied over the insulated surface and are carried over the edge and down the outside of the side wall for at least 4 in. A strip of saturated membrane fabric, 6 to 8-in. wide, applied around the circumference of the edge of the top and centered on the junction of the edge and side wall while the mastic is still wet, will further protect the joint from rain and moisture. A second ¼-in. layer of asphaltic mastic should then be applied and troweled smooth over the membrane fabric. * * *

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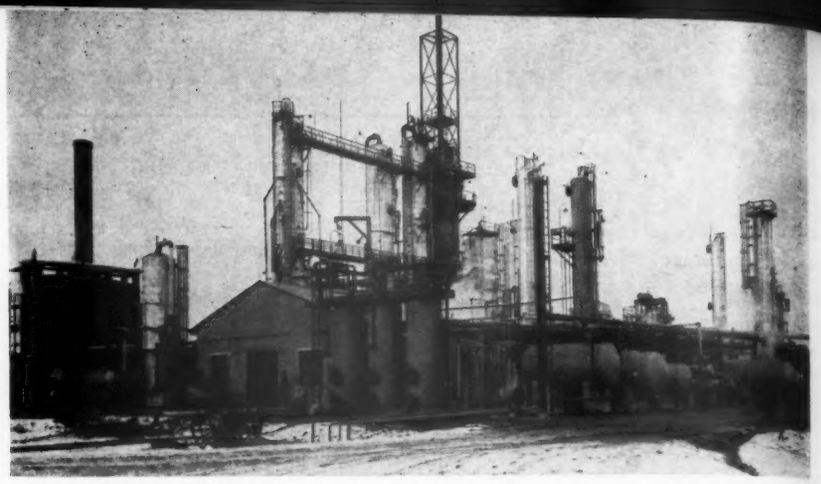


FIG. 1. Combination unit with crude heater cat polymerizer and gasoline stabilizer of 11,000 bbl refinery.

P 749.2

FULL Automation in Minnesota Refinery

Fred Kraus
Process Engineer
The Lummus Company, N. Y.

THE second refinery built since 1945 in the Upper Midwest, an area almost completely bypassed in the rapid, postwar refinery expansion, has been operated by International Refineries, Inc., for more than a year. Situated on 170 acres near Wrenshall, Minnesota, the plant has a rated throughput of 11,100 bbl per stream day and is probably one of the most fully automatic plants in the nation.

The refinery features a single unit construction, a continuous flow design, and the last word in futuristic automation. Its basic processes include crude distillation, catalytic cracking, gas recovery and polymerization, and product treating. Product blending, storage and loading facilities, boiler house, cooling water facilities, flare, administration building, shop, laboratory, and all other facilities required by an operating refinery have also been provided. Products made in the plant are: Regular gasoline, premium gasoline, range and diesel oils and No. 6 fuel oil. (Fig. 1)

The plant was specifically designed by The Lummus Company as a combination unit to achieve a substantial saving in construction cost by eliminating all intermediate storage and its accompanying pipes and tanks, as well as the maintenance connected with such equipment. The actual running of the refinery was reduced to six operators per shift who keep the crude moving continuously through the various processes from bulk storage to finished products.

Prior to construction of refineries in the area, petroleum products were brought to this section of the country by pipe line and by river barge in the summer time. The development of the Alberta fields and construction of the 1150-mile Interprovincial and Lakehead pipe lines made Redwater and Leduc crudes from these Canadian fields economically available. Development of crude production in the near-by Williston Basin in North Dakota has provided this area with an alternate crude oil source.

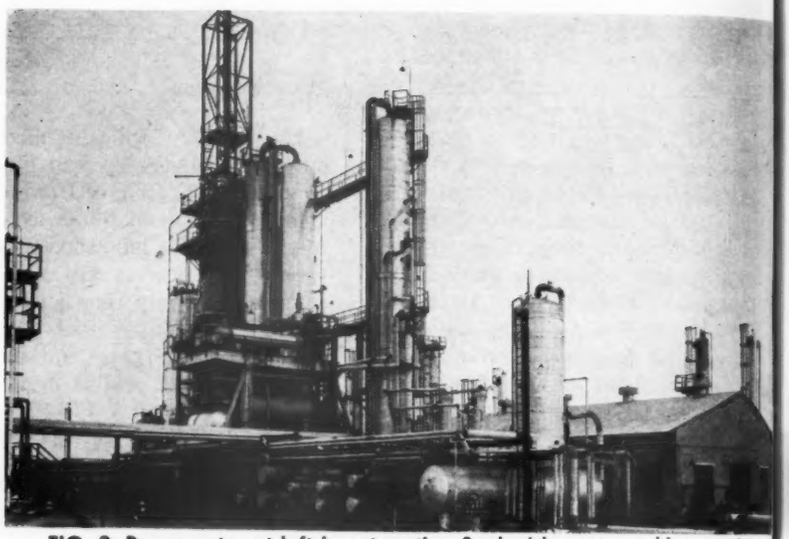


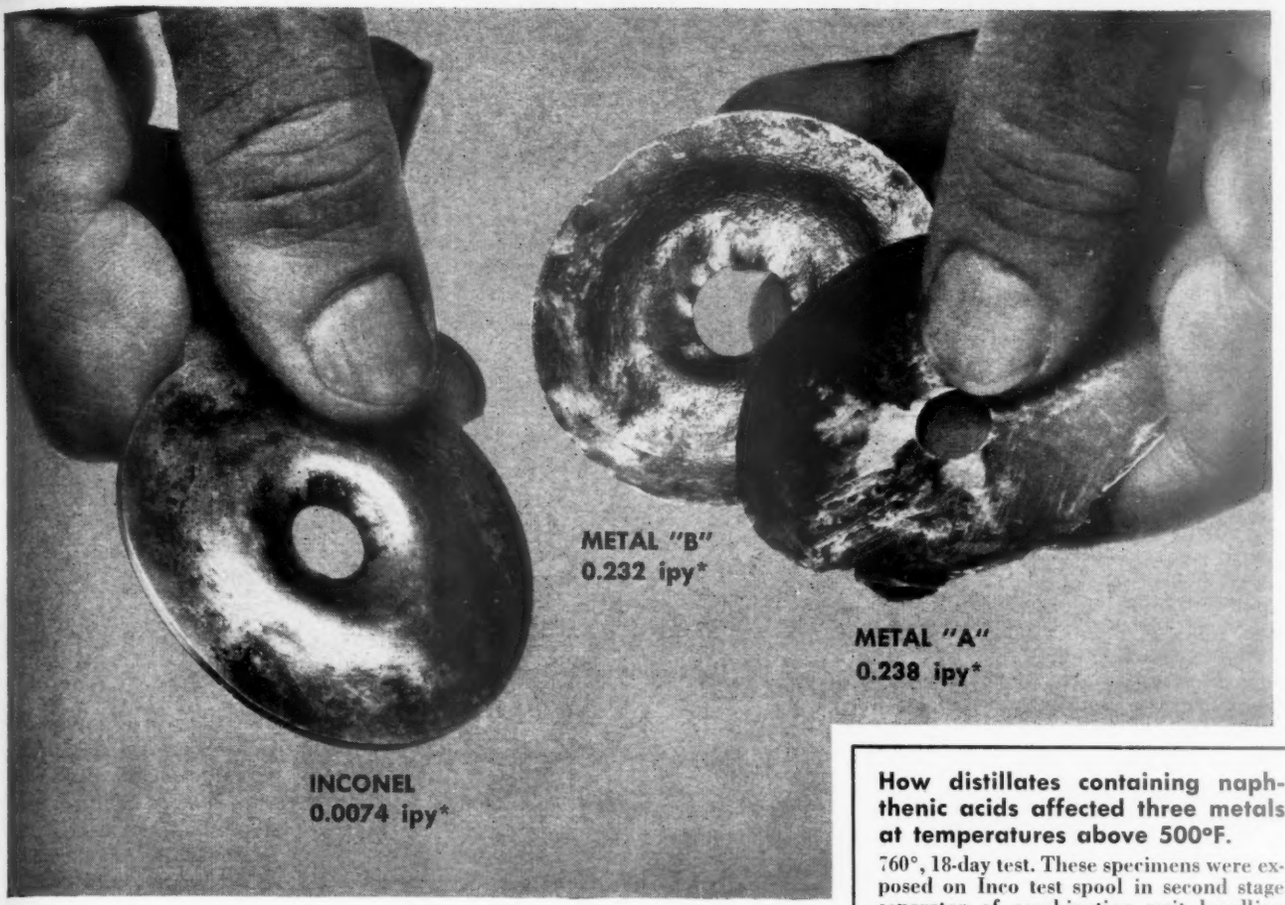
FIG. 2. Regenerator at left in cat section flanked by cat cracking reactor and main fractionator; at center is the crude distillation tower and desalter.

When charging Canadian crudes, the Wrenshall refinery runs at the rated capacity of about 11,100 bbl per day and produces approximately 5400 bbl per day of gasoline, 2800 bbl of range and diesel oils, and 2300 bbl of No. 6 fuel oil. When fed on Williston Basin crudes, the refinery charges about 12,500 bbl per day and produces approximately 7900 bbl of gasoline, 2800 bbl of range and diesel oils, and only 1000 bbl of No. 6 fuel oil. The refinery has also produced considerable quantities of high quality aviation jet fuel. (Fig. 2)

The Wrenshall refinery receives its crude either from the Lakehead Pipeline Company trunk line passing about one mile from the site, from where it is pumped bulk to storage, or from railroad tank cars in the case of Williston Basin crude. The crude is mixed with Tretolite and water, preheated by heat exchange to 220 to 240 F, and passed through two separate settling chambers where salt water is removed. From here, the desalted crude flows through the heater, which it leaves at 750 F, and enters the crude distillation tower (8 ft by 64 ft), in which it is separated into various products. Gas and straight-run gasoline are removed from the top and separated; the gas goes to fuel while the gasoline is stabilized and treated for sulfur removal and sweetening, and then is cut to storage. The range oil cut goes directly to the Doc-

All intermediate storage eliminated and operators cut to 6 per shift in stream-lined 11,100-bbl plant

EXCLUSIVE



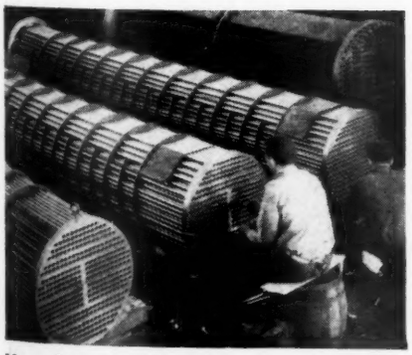
How distillates containing naphthenic acids affected three metals at temperatures above 500°F.

760°, 18-day test. These specimens were exposed on Inco test spool in second stage separator of combination unit handling cracked petroleum gas oil from Monaca crude (naphthenic base). Sulfur, 1.27%.

* ipy — inches penetration per year of continuous exposure

"Even above 500° F," test spools indicated,

"Inconel can prevent naphthenic acid corrosion"



How heat exchangers were made

1085 cold drawn seamless Inconel tubes were inserted into Inconel tube sheets 30½ in. dia., 2-1/16 in. thick, then welded. Strong, tough Inconel, like Monel and Nickel, is readily fabricated and welded. No after treatment needed.

...Now, *13 trouble-free years of service from heat exchanger tubes prove it.*

Even above 500°F, Inconel stands up under naphthenic acid corrosion. This was first shown years ago, when a certain South American refinery made "on stream" tests with specimens of several metals.

Because of these tests, the engineers specified Inconel for tubes and tube sheets in three heat exchangers. Thirteen years later, the equipment was still going strong.

Experience in other installations is comparable. In this application, Inconel not only resists naphthenic acids, but provides good resistance to sulfur attack and oxidation as well.

Another important reason why Inconel is often employed for heat exchanger tubes is the fact that it is highly resistant to stress-corrosion cracking in sea water and other chloride-containing waters. It can thus be used to resist both product- and water-side corrosion.

Are you having trouble with heat exchanger corrosion? Maybe, as in this case, Inco's Corrosion Engineers can help you find the metal that will handle it. Just write details.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

Inconel... an INCO TRADE MARK Nickel Alloy

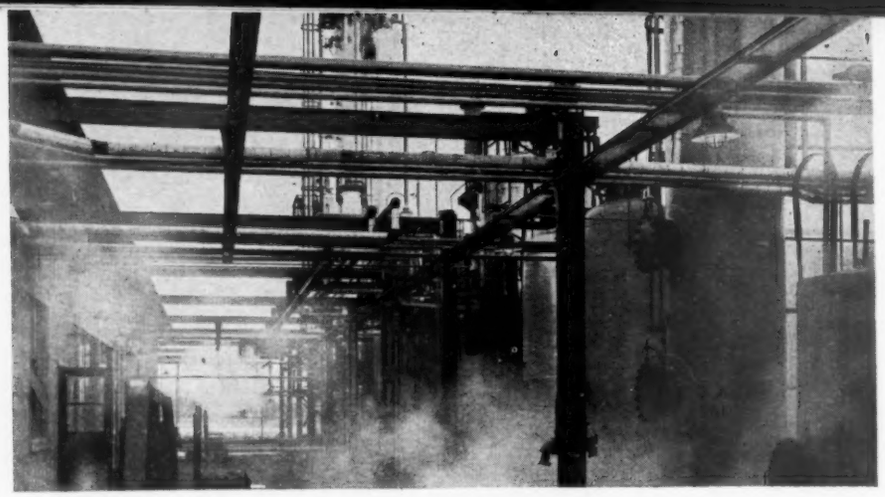


FIG. 3. View outside pump-house with process lines overhead shows column for extracting mercaptans from gasoline, and in center background the catalytic polymerization section.

tor Treating Unit where its odor and and corrosiveness are eliminated by mixing with Doctor solution (lead oxide and caustic) in a two-stage, continuous process. The first stage Doctor solution is continuously regenerated with air. The range oil is finally separated from the Doctor Solution in the second stage settling tank and pumped to storage. A gas-oil distillate is removed as a side-cut and pumped directly to the catalytic cracking reactor, a Model IV type developed by Standard Development Company, without the usual stop-over in intermediate storage. The reduced crude from the crude distillation tower goes to the main fractionator of the cat cracking section for further reducing; the gas-oil fraction from this further reduction is also charged to the reactor. (Fig.3)

The fresh charge to the Model IV fluid cat cracker amounts to 3070 bbl per day and recycle gas-oil to about 1800 bbl per day. Various improvements have substantially reduced the size of the Model IV cat cracker. The reactor is a vessel 7 ft-6 in. by 49 ft-8 in. and the regenerator is 12 ft by 30 ft-9 in.

Certain design features have materially improved operations. For example, catalyst transfer pipes have no sharp bends so that much erosion is eliminated. Cyclones have been re-designed to make catalyst recovery from the vapors more efficient. The diameter of the reactor and regenerator have been decreased and the velocity increased. Elimination of the throttling valves has lowered horsepower required on airblower for the generator.

The main fractionator, 8 ft-6 in. by 60 ft-6 in., separates the various products cracked in the reactor. The fractionator overhead of gas and gasoline is condensed to a stream of wet gas and "wild" gasoline and taken to the vapor recovery plant. Passed to a compressor, the gas moves to the absorption tower (3 ft by 55 ft-6 in.) where the butane, butylene and about 70 per cent of the propane-propylene are absorbed in absorption oil. The unabsorbed gas is sent to fuel and the rich absorption oil is returned to the main fractionator for stripping. The "wild" gasoline goes to the stabilizer (3 ft by 38 ft-6 in.), and the stabilized gasoline is caustic washed in a two-stage system and cut to storage.

The stabilizer overhead containing C_3 and C_4 is charged to the diethanolamine absorber where the H_2S is removed. The desulfurized hydrocarbons are washed in caustic and water, dried in a coalescer, and then charged to the Catalytic Polymerization reactor.

This reactor, developed by California Research Corporation, polymerizes the butylene and propylene present into polymer gasoline. This product then moves to the polymer stabilizer (2 ft-6 in. by 38 ft-6 in.) where the poly gasoline is separated from the gas and sent to storage; the separated gas is fed to the fuel system.

The reactor (5 ft by 38 ft-6 in.) is filled with catalyst which is regenerated in place. This catalyst consists of a quartz base with which the reactor is filled. Then 85 per cent phosphoric acid is pumped over the quartz until the entire vessel is full. After it has set for some time, the excess acid is drained off and the acid remaining in the pores of the quartz acts as catalyst. When the catalyst activity decreases to the point where economics indicates, the reactor is washed out and the catalyst regenerated.

Automatic Features

More than 80 indicators or recorders are mounted at their proper places in the flow diagram on the panel and show or record various processing variables from remote points in the refinery (Fig. 4). The same number of back-of-panel or locally mounted controllers are co-ordinated with the former to provide automatic control of the variables. From the panel, the operators can change pressures, temperatures, flows and levels throughout the refinery without leaving the room. It is truly a finger-tip control.

Temperatures are detected electrically by iron-constantan thermocouples and are converted into calibrated air pressures at the control panel by electronics non-indicating pneumatic transmitters. In turn transmitters actuate miniature recorders or indicators that act at same time as controllers to maintain temperatures at desired levels.

All process flows are measured by differential converter pneumatic-balance transmitters that convey their calibrated signals to other panel-mounted Tel-O-Set systems for their remote record and control.

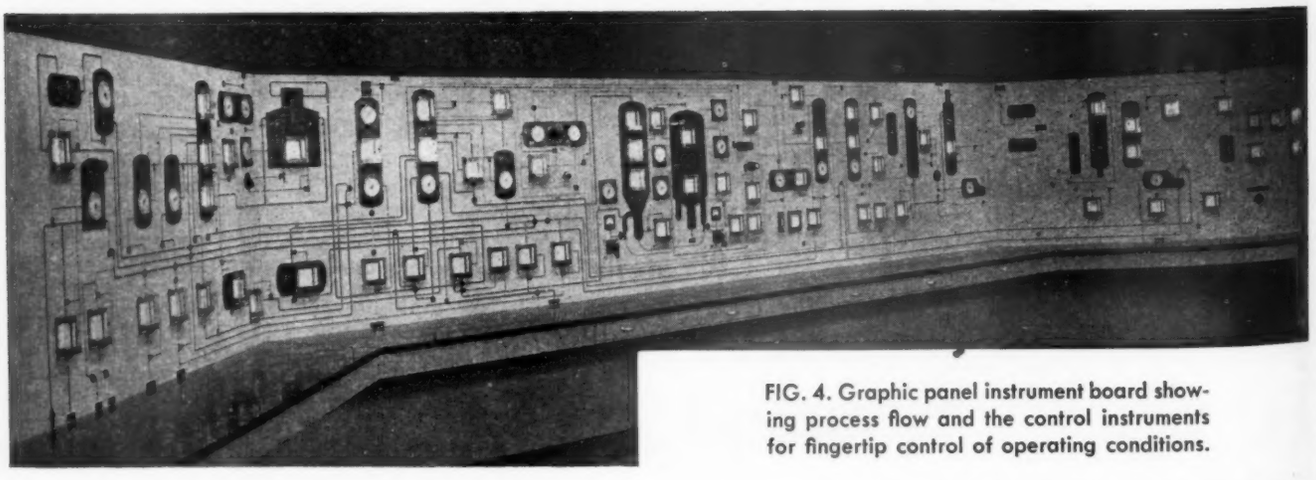


FIG. 4. Graphic panel instrument board showing process flow and the control instruments for fingertip control of operating conditions.

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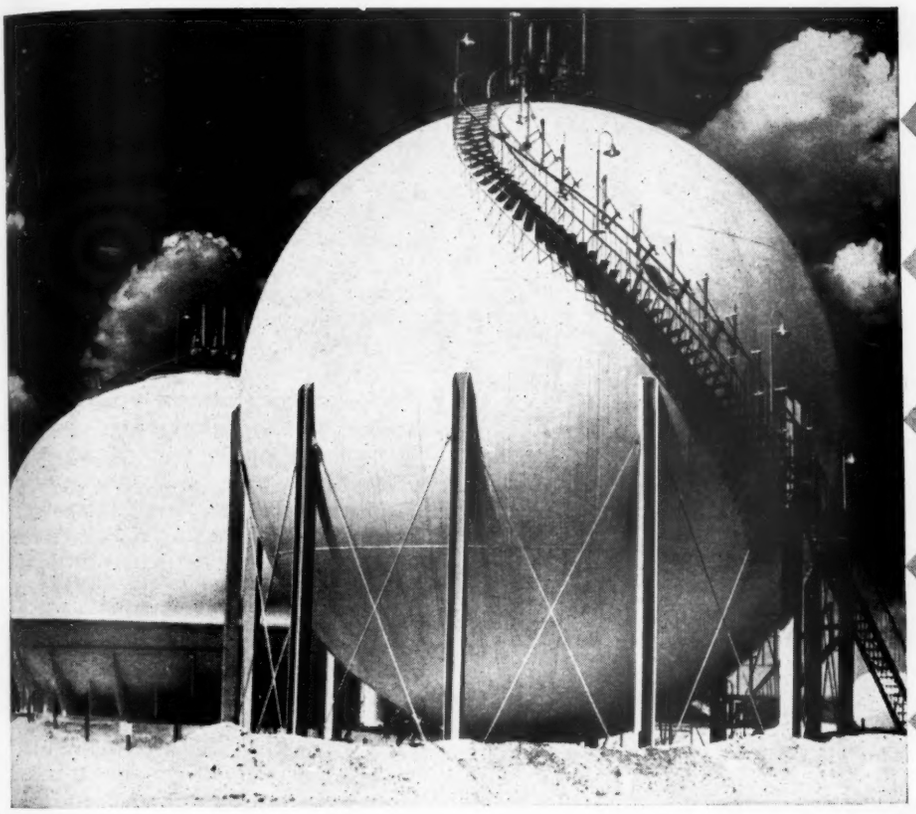

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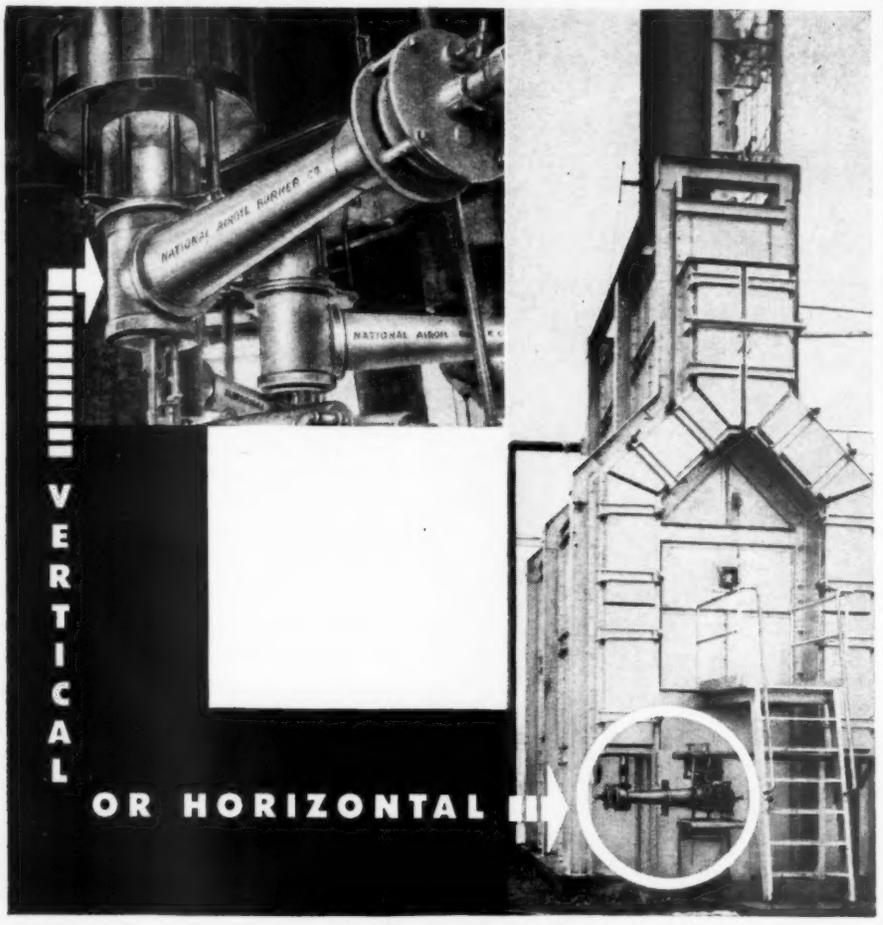

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Cascade Control Between Reactor and Regenerator

Pressures and temperatures in the fluid catalytic cracking unit are controlled by two new instrument applications called cascade control. Pressure is adjusted by controlling the exhaust from the regenerator; temperature is controlled by adjusting the flow of spent catalyst to the regenerator.

Pressure to control the flow of catalyst to the reactor is controlled by a differential pressure cell that detects pressure differences between reactor and regenerator and transmits its calibrated signal to the panel-mounted recorder-controller system whose output positions the set point of a miniature controller indicating pressure. This latter controller measures pressure in the regenerator and keeps it at the varying set point determined by the action of the first controller through an electric motor-driven slide valve in the regenerator stack. The pneumatic signal from the second controller is translated into a calibrated electrical pulse that throws an electronic bridge out of balance. Output from the bridge is amplified in an electronic relay and, through a forward and reverse line starter, energizes the motor on the the control valve. Motor serves to adjust the valve back in balance.

Temperature in the reactor is controlled by the second cascade control system that consists of a second pair of panel-mounted instruments, a temperature recorder, and a controller. The pneumatic output of this system is fed into a second miniature recorder to position its set point. With this instrument the flow of air of the spent catalyst riser to the regenerator is regulated at the level set by the temperature control system. ★★

The Author

Fred Kraus has been employed by The Lummus Company as a process engineer since 1942. During that time he has designed all types of petroleum processing plants. He is a graduate of MIT, receiving his BS in chemical engineering in 1935 and his MS in chemical engineering practice in 1936. He is an active member of the American Institute of Chemical Engineers and a licensed professional engineer in the State of New York.

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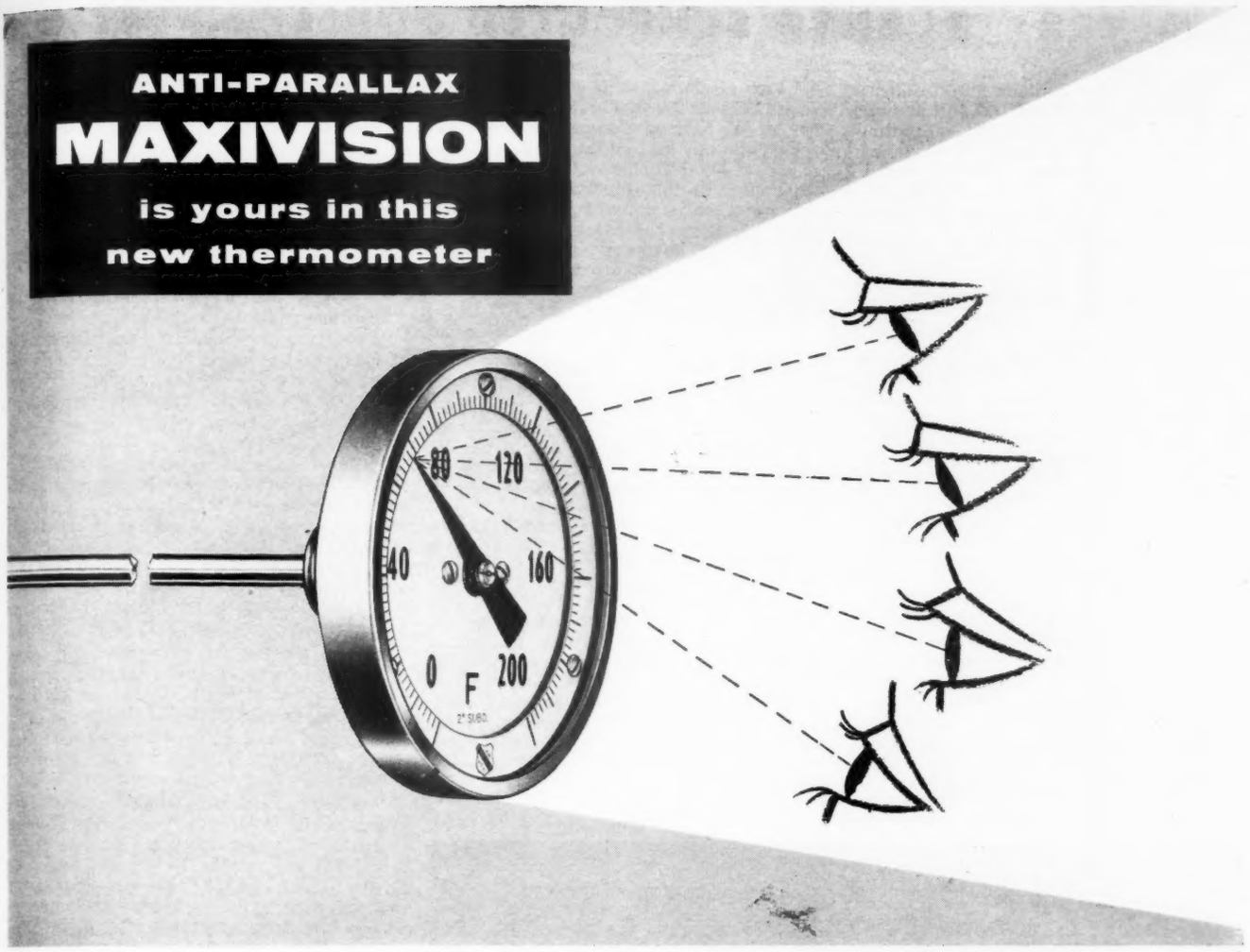

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SPECIFICATIONS

New AMERICAN ALL-STAINLESS STEEL BI-METAL THERMOMETER with ANTI-PARALLAX MAXIVISION DIAL

Dial: Exclusive anti-parallax Maxivision dial, with scale approximately 6" long. Pointer set at same level as scale.

Climate-Proof Case: All stainless steel. 3" diameter. Threaded bezel. Selected clear, extra-heavy cover glass. Heat-resistant gaskets between glass and case seal the thermometer against rain, frost, sand, dust, fumes—climate-proof.

Temperature Ranges: From minus 80° to plus 1000° F. Accuracy within 1% of range.

Low-Mass Bi-Metal Coil: Welded to stem plug. Accurately centered in stem. Non-freezing, non-corrosive silicone fluid on coil dampens vibration, accelerates heat transfer, speeds response; does not gum, resists capillary action.

Pointer: Index type. Easily accessible from front of dial for positive adjustment over entire range. Pointer shaft guided by friction-free bearings.

Stem: 18-8 stainless steel, mirror polished. All joints welded. Resists corrosion. Provides strong, rigid and tight closure against process pressures. Lengths: 2½" to 24".

Connection: Fixed, ½" N. P. T.

Separable Sockets: Available for use in closed systems or where measured medium is corrosive to the stainless steel stem. Fit over all standard stem lengths except 2½".

AMERICAN INDUSTRIAL INSTRUMENTS

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'ASHCROFT' GAUGES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, *Stratford, Conn.* HANCOCK VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Oklahoma.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*

REFINERY PLANTS SCHEDULED FOR COMPLETION

Oil refinery for Jordan. An oil refinery to cost more than $5,000,000 will be built in the Jordan Said Allaeddin, according to the Minister of Economy. This refinery is expected to produce 250,000 tons of refined oil annually, valued at $8,000,000. The crude oil to be refined will be tapline line oil passing through Jordan.

★ ★ ★

New Yorktown, Virginia, refinery. The start of construction of the 35,000 bbl-per-day refinery for American Oil Company near Yorktown, Virginia, will occur by mid-summer 1955, announcement says. M. W. Kellogg Company is designer-builder. Units will include an atmospheric-vacuum crude unit of 35,000 bbl per day; 30,000 bbl per day Orthoflow fluid cat cracker; catalytic polymerization unit with treating capacity for 35,000 bbl per day of gasoline and the same capacity for kerosine, and a gas recovery unit to capture 95 per cent of the propane-propylene produced in the plant.

★ ★ ★

LPG plant in Canaries. Compañia Espanola de Petroleos, S. A., (CEPSA) is planning to install a bulk LPG storage and distribution plant at its Teneriffe refinery in the Canary Islands. This station is to be equipped with ample storage tanks and all the facilities necessary for the bulk delivery by water of LPG gas.

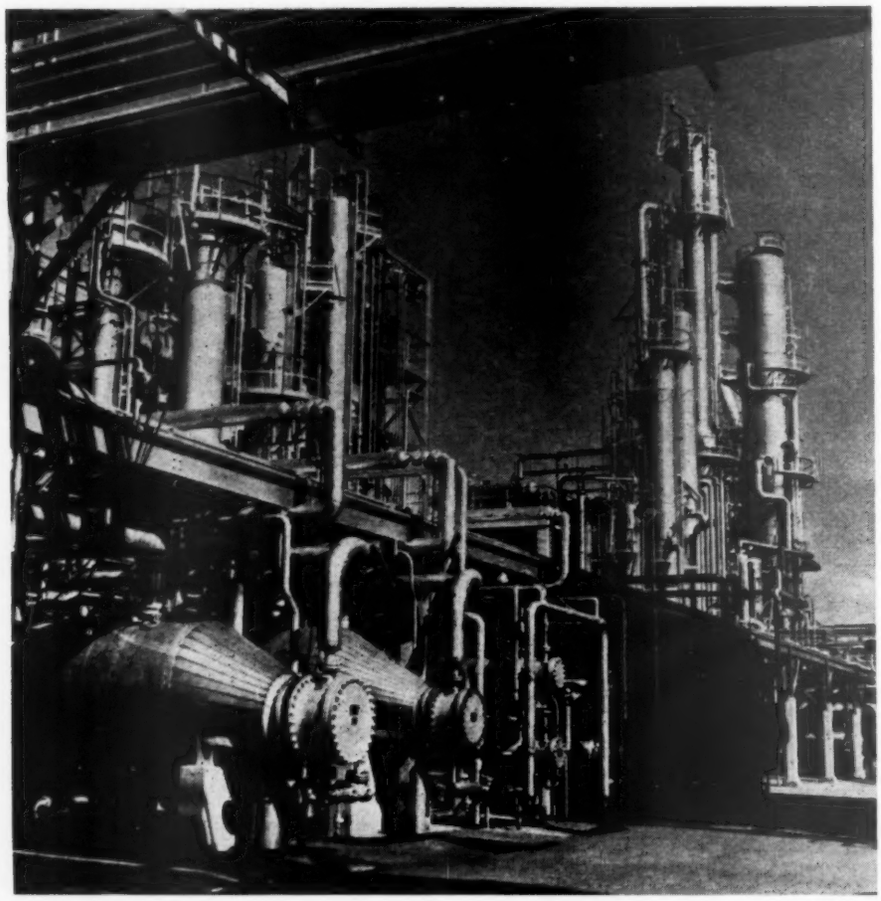
Two Gulfining units contracted. Contract has been let by Gulf Oil Corporation to M. W. Kellogg Company to build two new Gulfining units at Port Arthur, Texas, each of 20,000 bbl per day capacity, for upgrading heating oils made at that plant. The process is a hydrogenating routine that improves burning and heating oils greatly, the company states. Hydrogen sulfide will be produced which will be processed in turn to recover 20 to 40 tons of free sulfur daily.

★ ★ ★

Cat cracker at Daikyo refinery. The first Houdriflow cat cracker in the East has started operating at the refinery of Daikyo Oil Company at Yokkaichi, Japan. It will crack 4200 bbl per day of gas oil. Unit was designed by Houdry Process Corporation and built by a Japanese firm of engineers.

★ ★ ★

Champlin starts platformer. As part of its modernization program, Champlin Refining Company at Enid, Oklahoma, subsidiary of the Chicago Corporation, started into operation a new platformer catalytic polymerization unit of 5000 bbl per day capacity. Soon a catalytic polymerization unit will be operating, making polymer gasoline component from thermal and catalytic unit gases. Company is spending $4,000,000 on new equipment.



Commissioning of a new catalytic cracking unit will increase petroleum production to 500,000 tons a year at the refinery at Antwerp, Belgium, jointly owned by British Petroleum and Petrofina. Exchangers and fractionating towers of the plant are shown in photograph.

Anderson-Prichard platformer. A $750,000, 5000 bbl-per-day platformer is contracted for by A-P and has been let to Southwestern Engineering Company of Los Angeles, California. Unit goes in at Arkansas City, Kansas, formerly the Arkansas City Refining Company refinery.

★ ★ ★

SOCal platformer operating. One of two new platformer-unifier units has gone on stream for Standard of California at Richmond refinery. Unifiner is feed preparation unit for the reformer and has 22,000 bbl per day capacity. The second platformer-unifiner is building at El Segundo refinery.

★ ★ ★

Water treating unit at Halifax. Water processing facilities to cost $500,000 are being built by Imperial Oil, Ltd., at Imperoyal, Nova Scotia, near Halifax. Water from the harbor is employed in cooling in the refinery, and the new capacity is planned to prevent any contamination being returned to the harbor with the rejected cooling water return. It will handle 35,000,000 gal per day.

★ ★ ★

More platformer-unifiner units. Two platformer-unifiner units are on stream for Texas Company at Port Arthur, Texas (20,000 bbl per day), and at Lawrenceville, Illinois (13,000 bbl per day). Both units were built by Lummus Company. The Port Arthur unit can be "blocked out" to produce aviation fuel base stock for gasoline engine power. The unifiners use a cobalt-molybdenum catalyst to prepare feed stock for the reformers. Fluor Corporation will build a similar combination unit at Texaco's Casper, Wyoming, refinery.

★ ★ ★

Phillips ammonia in Northwest. Phillips Pacific Chemical Company has been formed, a subsidiary of Phillips Petroleum Company and Pacific Northwest Pipeline Corporation, to build an ammonia plant in southeastern Washington. The two companies will own and operate the new company. Plant will synthesize 200 tons per day of ammonia to supply fertilizer to the northwest area. Fish Engineering Corporation will build the plant. Natural gas from San Juan Basin, northwestern New Mexico and southwestern Colorado, will supply the raw materials.

★ ★ ★

Urea plant for West Coast. A more-than-100-tons per-day urea plant will be built soon by Shell Chemical Company, the first urea plant west of the Rockies. Urea contains a higher percentage of nitrogen than any other solid fertilizer. Process is the Montecatini of Italian origin. M. W. Kellogg Company is the contractor. Water soluble, urea can be fed to plants via leaves as well as roots. It is also used in making resins, adhesives, and in cattle feed. It has been tested with very good results on western crops. The new unit is scheduled to be in operation by September, 1956.

Florida refinery contracted. Construction of a 15,000 bbl per day refinery at Fort Pierce, Florida, has finally been agreed upon, with building to start soon and completion expected in August, 1956, Seminole Oil Company announces. Refinery will process crude containing about 6 per cent sulfur derived from the production of Sharples Oil Company in Mexico. Seminole vice president is P. T. Sharples, board chairman of Sharples Oil Company; president is Gerald Peters of a Denver investment company; refinery superintendent is Harry Brown, vice president of Frontier Refining Company, Cheyenne, Wyoming. Frontier Refining will own 20 per cent of the stock; Sharples, and J. Noyes, of a New York investment firm each 15 per cent; Frontier will operate the plant.

★ ★ ★

Canadian Industries, Ltd., (CIL) ammonia plant. This unit is already under construction at Milthaven, Ontario, Canada. It will cost $9,000,000 and will make 200 tons per day of ammonia. CIL's capacity at Beloeil, Quebec, for making ammonia solutions is being expanded also.

★ ★ ★

First Houdry plant in Europe. The first European unit for production of butadiene from normal butane by the single-step Houdry Dehydrogenation Process will be installed by Chemische Werke Huels A. G. at Marl, Kreis Recklinghausen, West Germany. Unit will be operated by a newly-formed company, of which Chemische Werke Huels will be half-owner. The plant's annual production of 36,000 metric tons of butadiene will be used for the manufacture of synthetic rubber, and the project is regarded as the first step in development of a modern synthetic rubber industry in West Germany.

★ ★ ★

Perchorethylene unit planned. Design of a new unit for the production of perchlorethylene is being done for Pechiney, major French chemical manufacturing firm, at St. Auban, France. It uses the direct chlorination process, operating on methane ethane or propane, instead of the four-times-as-expensive acetylene used elsewhere for this important chemical intermediate.

★ ★ ★

Gas turbines for Venezuela. Twelve 7000-hp gas turbines, totaling 96,000 bhp, the largest concentration of gas turbine power in the world, will drive the centrifugal compressors, sending 300,000,000 cu ft of gas daily into the earth in the Lake Maracaibo, Venezuela, oil field. These Westinghouse units will be completed by August, 1956.

★ ★ ★

Starting Tide Water plant. Grading of 450-acre plant site for the 130,000 bbl-per-day refinery for Tide Water Associated Oil Company near Delaware City began in June. Two million, four hundred thousand cubic yards of earth will be moved, including 500,000 cu yd of top-soil that will be removed and replaced later as topsoil coverage about the plant. Building at peak will call for 4000 workers, with plant completion date late in 1956 by C. F. Braun & Company.

★ ★ ★

Solvay's ammonium bicarbonate plant expansion. Solvay Process division's new ammonium bicarbonate plant, located at Syracuse, New York, and completed in 1952. is already undergoing needed expansion. No additions to the building will be required, but new equipment is currently being installed which is expected to increase the productive capacity of this operation by more than 25 per cent before the end of 1955. Solvay is a division of Allied Chemical and Dye Corporation.

★ ★ ★

Butadiene-avgas plant. A $26,000,000 alkylate-avgas and butadiene plant will be built by Texas Butadiene and Chemical Corporation in the Houston, Texas, area, to be completed by December, 1956, that company has announced. A facilities contract has been granted by the Armed Services Petroleum Purchasing Agency, and the Office of Defense Mobilization has issued a certificate of necessity. Wide flexibility of operation is attained by this combination of processes to give capacities of 2,500,000 bbl of avgas and 17,000 tons of butadiene annually, with reduction of avgas production and increase of butadiene output up to 43,000 annual tons when making all butadiene. Purvin & Gertz, consulting engineers of Dallas, developed the combination of avgas and butadiene processes and designer-contractor is the Fluor Corporation, Ltd., of Los Angeles, California. Largest stockholder is Godfrey L. Cabot, Inc., while E. L. Green, Jr., vice president, Cabot Carbon, is president. Carl M. Loeb, Rhoades & Company, investment bankers, are also interested.

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To obtain more information on products advertised see page E-27

REFINING AND PETROCHEMICAL

PERSONALS

▸ **Richard C. Alden** has been elected a director of American Society for Testing Materials for a three-year term. He has been with the research department of Phillips Petroleum Company since 1925, became its assistant director in 1930, director in 1933, and chairman of the research planning board in 1950.

Active in ASTM work since 1939 Alden is now first vice chairman of committee D-2 on petroleum products and lubricants, and a member of the administrative committee on research. He holds offices or membership in several subcommittees of committee D-2 and is a member of one subcommittee in committee D-11 on rubber. Alden was graduated from Lehigh University in 1918, served in the Signal Corps during World War I, and worked successively for Bethlehem Steel Company, Chestnut and Smith Corporation, Seeley-Oberfell Engineering Corporation; and as California sales engineer, Gasoline Recovery Corporation.

▸ Humble Oil & Refining Company announces the following personnel additions and changes at its Baytown, Texas, plant: **W. R. Edwards,** BS in chemical engineering, North Carolina State College to research and development division; and to technical service division, **D. M. Allen,** BS in chemical engineering, Texas Technological College; **R. G. Henry,** BS in chemical engineering, Oklahoma A&M College; **R. B. Nesbitt, W. H. Oliver,** and **J. E. Spell,** BS in chemical engineering, Texas A&M College, and **R. C. Savoie,** BS in chemical engineering, Rice Institute.

The following have returned from military service. **L. E. Singleton,** BS in mechanical engineering, Louisiana State University, to engineering division; and **C. D. Strickland,** BS in chemical engineering, Louisiana State University, and **J. J. Bloess,** BS in chemical engineering, Missouri School of Mines, to technical service division.

S. H. Hastings has been named research specialist in research and development division. He holds the BS degree in chemistry from University of Houston, and the MS and PhD degrees from The University of Texas. Dr. Hastings will specialize in physical analytical methods with particular emphasis on higher boiling petroleum fractions.

▸ **Dr. Robert D. Englert** has been named manager of Stanford Research Institute's Pasadena Laboratory. His appointment coincides with plans to extend project work of the laboratory into the fields of chemistry and chemical engineering. He has worked with SRI since 1949.

He holds degrees from the University of Portland and Oregon State College and a PhD from Colorado. He holds several patents on insecticides, and is a member of American Chemical Society, Sigma Xi, Phi Lambda Upsilon and Research Society of America.

R. D. Englert

J. W. Nixon

▸ **John W. Nixon** has been appointed plant manager for the National Petro-Chemicals Corporation, Tuscola, Illinois. He has been chief engineer at the plant since 1952 when he was first employed by Petro. His previous experience includes 18 years with a major oil company.

Other promotions announced by Petro-Chemicals are **Charles D. Carnes** to chief engineer; **George A. Siegelman** to assistant plant manager; **Clifford E. Oman** to assistant plant superintendent, and **Robert E. Jones, Jr.** to area superintendent of alcohol and ethyl chloride processes.

▸ **Richard W. Campbell** has been promoted to manager of the Los Angeles district of Shell Chemical Corporation, replacing **J. E. Toeves,** recently appointed sales manager of the company's newly created synthetic rubber sales division.

Jack C. Dart

A. G. Oblad

H. D. Hartough

Ray Cross

▸ **Jack C. Dart,** manager of research and development and member of board of directors, has been named manager of the new catalyst-marketing chemical division of Houdry Process Corporation. **Dr. Alex G. Oblad** succeeds Dart as manager of Houdry's research and development laboratories at Linwood, near Marcus Hook, Pennsylvania. **Howard D. Hartough,** research section head, becomes director of product sales and market development of chemical division. And **Ray Cross,** manager, Houdry catalyst manufacturing plant, Paulsboro, New Jersey, becomes director of product manufacture, chemical division.

▸ **William C. Soudriette** and **Harold W. Torgeson** have been appointed staff assistants to **William T. Cravens,** manager of Cities Service Oil Company's Refining division. Soudriette's new duties as staff assistant will deal primarily in the field of refinery operations and research. Torgeson's duties will be in connection with lubricants manufacture and application. Soudriette, joined Cities Service in 1947 at its East Chicago, Indiana, refinery as an engineer. He served as process engineer, catalytic cracking foreman and, in 1953, was named assistant cracking foreman at East Chicago. He is an engineering graduate of Rose Polytechnic Institute. Torgeson was first employed by the company in its junior engineer training school in 1947. His first permanent assignment was at the company's Ponca City, Oklahoma refinery. He was transferred to Bartlesville in 1949 to supervise the company's lubricating oil and grease operations. He is an engineering graduate of Kansas University.

▸ **Frank V. Williams,** formerly manager of the Socony Mobil Oil Company refinery at Olean, New York, has been appointed assistant manager of the lubrication and special products department of Standard-Vacuum Oil Company. Socony Mobil owns a half-interest in Standard-Vacuum. Williams' headquarters will be in the New York office. He received a BS degree in mechanical engineering from Drexel Institute of Technology and did post-graduate work at Temple University before joining Socony Mobil in 1935 at its Paulsboro, New Jersey, refinery. He remained there until 1945, when he was transferred to Olean.

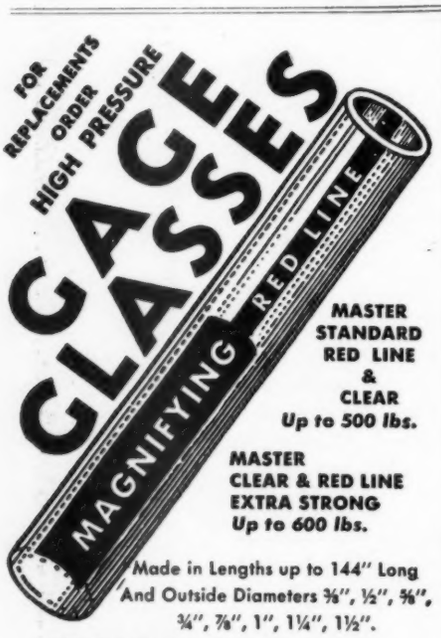
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FIG. 21—Lip Mold

FIG. 22—Standard

ERNST WATER COLUMN & GAGE CO.

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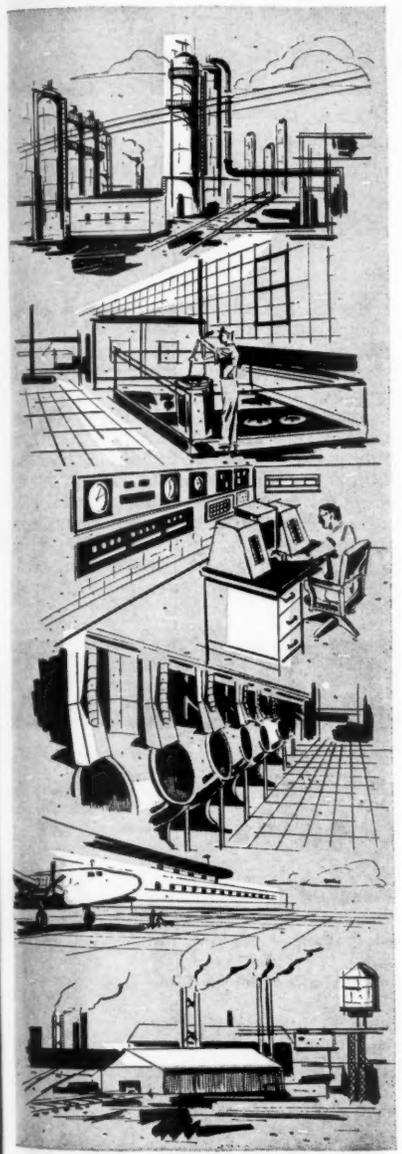
A MESSAGE TO CONSULTING ENGINEERS

Have you noticed how frequently you're being asked for recommendations on DRYing? For example, if your specialty is one of these:



PETRO-CHEMICAL—Extreme DRYness is often required for the air, gases and organic liquids involved in processes . . . a moisture content of 3 to 4 parts per million, or less. Otherwise, reactions are likely to go wrong and product quality suffers.

METAL-WORKING—DRY controlled atmospheres are necessary in many heat-treating and sintering operations. Metals must be stored, parts inspected and assembled in DRY rooms to prevent corrosion. Costs are correspondingly lower.

POWER GENERATION—Pneumatic controls must be fed DRY air to prevent freeze-ups and clogging of delicate instrument ports. Control rooms are dehumidified to improve performance. The hydrogen that cools generators is kept DRY to safeguard their electrical insulation.

PHARMACEUTICAL—Areas in which hygroscopic materials are handled, whether they're tiny cubicles or complete workrooms, must be kept DRY. 10% relative humidity is common in industry. Precautions must be taken to prevent leakage of moisture into these areas and maintain this DRYness.

AIRCRAFT—Flight conditions at stratospheric heights in frost-free air must be simulated for airplanes, components and missiles. Wind tunnels and altitude test chambers must operate, therefore, at dewpoints below −100°F.

GENERAL INDUSTRY—Foodstuffs and jet engines have this in common: both are packaged in DRY inert atmospheres to prevent their deterioration. Wherever moisture is a hazard, it can probably be eliminated or held to a known, predictable constant. DRYing, then, becomes a matter of economics, balancing costs against gains.

Make someone in your organization an expert on DRYing . .

Be prepared for these requests when they come in. You select the man and we'll gladly assist in his education. Send us his name and we'll send him the book, *Because Moisture Isn't Pink*, and other data. Pittsburgh Lectrodryer Corporation, 334 32nd Street, Pittsburgh 30, Pennsylvania.

PITTSBURGH LECTRODRYER CORPORATION

New teaching professorship in chemical engineering will be set up by Cornell University with $60,000 given by Socony Mobil Oil Company, Inc. Prof. Fred H. Rhodes, left, is shown accepting gift for Cornell. Center is William M. Holaday, director of Mobil Research Laboratories, and right, Prof. J. Eldred Hedrick, assistant engineering dean.

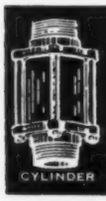
Dr. Joseph G. Davidson, chairman of the Carbide and Carbon Chemicals Company, center, receives the honorary degree of Doctor of Science from Dr. Fred D. Fagg, Jr., left, president of the University of Southern California. Dr. Robert E. Vivian, right, dean of the School of Engineering, Southern Cal, presented the candidate.

▸ **R. W. Gerhard** has been appointed director of the coordination division in the distribution economics department of Standard Oil Company (Indiana). He has been supervisor of cost control in general office of the manufacturing department. He joined the company in 1944 as a chemical engineer at the company's Wood River, Illinois, refinery.

▸ **David G. Reynolds** has joined the staff of Ehrhard and Arthur, Inc., engineers and constructors, as chief process engineer. He has had 15 years of continuous experience with major process designers and engineering contractors previous to his present position. His new duties involve direction of process design work for refinery and chemical units built by Ehrhart and Arthur, Inc.

▸ **Russell J. Cameron** and **John B. Jones, Jr.** announce the formation of an engineering and consulting firm specializing in oil shale technology, with **Arthur Matzick** as associate.

The officers and associates are formerly senior staff members of the U. S. Bureau of Mines oil-shale experiment station at Rifle, Colorado. The company offers the following specific services: Process design, process development, economic evaluation, plant engineering, plant operation and general consultation. Offices are at 100 East Jefferson, Englewood, Colorado.



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For cutting sample plugs from oil well cores. Also may be used for drilling holes in cores.

Bit is made of chromium molybdenum steel with an annular crown of industrial diamonds mounted in a matrix of cemented carbide on the cutting end. In order to insure concentricity, all machining is done after diamonds are mounted on the bit. Standard length allows drilling to 3-inch depth.

Thermo-Plumb Bob

Carries down tape — reads oil temperature — measures water in tank bottom. A six-inch, 15-ounce brass plumb bob, hollowed out to form an oil cup, and equipped with thermometer for reading temperature of oil. On back of plumb bob is a 6-inch scale which can be used to gauge the amount of water in the bottom of the tank by use of Gage-0 water finding paste.

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PIPE LINE DEVELOPMENTS

★ ★ ★

Roundup of Current Planned and Proposed Construction

NAME OF COMPANY	MILES	PIPE SIZE	LOCATION
CRUDE LINES			
Ar-Mex Pipeline Co.	790	12-14	Guernsey, Wyoming to Coolidge, Arizona
Big Horn Pipe Line Company	150	8	Ash Creek field to Midwest station of Service Pipe Line, Wyoming
Keybee Pipe Line Company	46	10	Griffith, Indiana, to New Buffalo, Michigan
Michi, Inc.	222	10	Highland, Indiana, to Elsie and Alma, Michigan
NNCW Pipe Line Co.	127	8-10	Weston County to Casper, Wyoming
Orchard Pipe Line	45	8	Orchard to Merino, Colorado
Peace River Oil Pipe Line Co., Ltd.	200	12-16	Peace River area to Edson station on TransMountain near Edmonton, Alta
Powder River Pipe Line Company	436	10-16	Williston Basin to Laurel and Billings, Montana
Proven Oil & Refining Company	32	8	Connection with West Coast Pipe Line to Florence, Ariz.
Roosevelt Oil & Refining Corp.	22	4.6	St. Helen to Norwick, Michigan
West Coast Pipe Line Company	960	20-22	Wink, Texas, to Norwalk, California
Union Oil Co.	815	—	Rifle, Colo. to Los Angeles, Calif.
U. S. Department of Defense	97	—	Crude line from Elk Hills Naval Reserve to Los Angeles, California
PRODUCTS LINES			
American Pipe Line Company	1910	8 to 26	Beaumont, Texas, to Newark, New Jersey, with laterals
Ar-Mex Pipe Line Company	130	8	Tucson to Coolidge to Phoenix, Arizona
H. W. Bass & Sons, Incorporated	152	4-6	Duval and Live Oak counties, Texas, to Corpus Christi, Texas
Bell Oil and Gas Company	140	6-8	Ardmore to Cushing, Oklahoma
Bowen Oil and Management Company (LPG Line)	460	10	Midland to Texas City, Texas
Buckeye Pipe Line Company	200	8	Conversion of existing crude line from connection with Wolverine Pipe Line near Michigan-Ohio border to Cleveland, Ohio
California-Oregon Pipe Line System	103	6	Crescent City, California, to Medford, Oregon
Deep Rock Gas Company (LPG Line)	120	6	Tioga, North Dakota to U. S. Canadian Border
El Paso Natural Gas Co. (LPG Line)	119	3-6	Bloomington to Gallup, New Mexico
Great Lakes Pipe Line Co.	106	12	Des Moines to Iowa City, Iowa
International Pipe Line Inc.	132	8	Wrenshall to Minneapolis, Minnesota
Keystone Pipe Line Company	48	8	Boot Station to Fullerton, Pennsylvania
Malco Pipeline, Inc.	91	6	Prewitt to Albuquerque, New Mexico
Mayflower Pipe Line Company	400	10	New Jersey refineries to New England points
Moore-Stoner Company	200	6	Glendive, Montana, to Minot, North Dakota
Phillips Petroleum Company	50	—	Ethylene line from Sweeny to Pasadena, Texas
Shamrock Pipe Line Corp.	100	6	Amarillo to Abernathy, Texas
Sioux Oil Company	50	6	Newcastle, Wyoming, to Rapid City, South Dakota
Southern Pacific Pipe Lines Company (300 miles have been contracted)	500	6 to 16	New products lines system in California, Arizona, New Mexico and Texas to be built and operated by Southern Pacific Railroad Co.
Sunflower Pipe Line Company (LPG Line)	265	3-6	Kearny, Grant and Haskell counties to Wichita, Kansas
Winnipeg & Central Gas Co. (LPG Line)	330	6	Tioga, N. D., to Winnipeg
GAS LINES			
Alberta Gas Trunkline	315	18-36	Gas Gathering System in Alberta fields
American-Louisiana Pipe Line Company	1120	22 & 30	Lowry, Louisiana, to Detroit, Michigan
Arkansas-Louisiana Gas Company	136	8 to 24	Loops on System
Atlantic Seaboard Corp.	82	26	Virginia, West Virginia, Maryland
Cities Service Gas Co.	93	26	Blackwell, Okla., to Independence, Kans.
Cities Service Gas Co.	145	—	Gathering systems in Woods County, Okla., Barber County, Kans.
Coastal Transmission Corporation (c/o Delhi Oil, Dallas)	400	30	McAllen to Beaumont, Texas
Colorado Interstate Gas Company	365	22	Green River, Wyoming to Denver, Colorado
Colorado Interstate Gas Company	110	6-8	Julesburg area to Denver, Colorado
Colorado-Western Pipe Line Co.	328	16-18	Ignacio field to Pueblo and Denver
Colorado-Western Pipe Line Co.	454	—	Cortez to Denver System
Colorado-Western Pipe Line Co.	250	—	Lateral lines
East Ohio Gas Co.	112	30	Maumee, Ohio, to Cleveland
El Paso Natural Gas Co.	370	—	Mountain Home, Idaho, to Reno, Nevada
El Paso Natural Gas Co.	74	—	Additions to Permian Basin-San Juan Basin system
Houston, Texas, Gas & Oil Co.	600	30	Baton Rouge, La., to Miami, Fla.
Houston, Texas, Gas & Oil Co.	350	18-24	Baton Rouge to Miami
Kansas-Nebraska Natural Gas Company	206	6-12	Additions to Nebraska system
Lone Star Gas Co.	230	30	Cotton County Oklahoma, to Fritch, Texas
Manufacturers Gas, Light & Heat	40	—	Allegheny, Washington, and Beaver counties, Pa.
Manufacturers Gas, Light & Heat	213	3 to 26	Various points on system in Pa., W. Va. and Ohio
Manufacturers Gas, Light & Heat	72	16-20	Doddridge, Wetzel and Marshall counties, West Va.
Michigan-Wisconsin Pipe Line Company	252	4-24	Loops and stations in Illinois
Mississippi River Fuel Corporation	190	10-18	Laterals in Woodlawn and Waskom gas fields, Texas
Morganfield Natural Gas	31	4-6	Through Sturgis, Providence, Clay, Diamond, Wheatcroft and Sullivan, Kentucky
Natural Gas Pipe Line Co. of America	350	20-26	Amarillo to Wise County, Texas
Natural Gas Producer, Inc.	100	12	Yenter pool to Denver, Colorado
Natural Gas Producer, Inc.	61	4-10	Northeast Colorado lines
North Dakota Natural Gas Company	475	6-12	Statewide system in North Dakota
Northern Natural Gas Company	330	2-12	System in South Dakota
Northern Natural Gas Company	310	24	Lines in North Dakota
Northern Natural Gas Co.	403	24-30	Canadian border to Minneapolis-St. Paul
Northwest Utilities Ltd.	42	—	Bonnie Glen to Edmonton, Alberta, Canada
Pacific Gas & Electric Co.	190	34	Topock, Ariz., to Milpitas, Calif.
Pacific Northwest Pipeline Corp.	931	14-26	Ignacio, Colorado to Bellingham, Washington, 555 miles are under construction
Pacific Northwest Pipeline Corp.	380		Laterals and spurs off main line to Pocatello, Idaho, to Yakima, Washington
Pine Tree Natural Gas Co.	204	—	Boston to Banger, Maine
Shenandoah Gas Company	39	3-4-8	Middleton, Virginia, to Martinsburg, West Va.
Tennessee Gas Transmission Co.	221	26 & 30	Loops in Ohio and Kentucky
Tennessee Gas Transmission Co.	376	6-24	Gathering lines in Louisiana and Texas
Texas Eastern Transmission Corp.	377	30	Beaumont, Texas, to Kosciusko, Miss.
Texas Gas Transmission Corp.	77	26	Covington to Jefferson, Ky.
Texas Gas Transmission Corp.	14	20	Haughton, La.
Texas Gas Transmission Corp.	72	12	Hardinsburg, Ky., to Bedford, Louisiana
Texas Gas Transmission Corp.	50	30	Bastrop, La., to Clarksdale, Miss.
Texas Gas Transmission Corp.	105	20	Eunice to Morgan City, La.
Trans-Canada Pipe Lines, Ltd.	2247	14-34	Alberta area to Toronto, Montreal
Transcontinental Gas Pipe Line Corp.	315	36	La., Miss., Va., Md., Ala., Ga., S. C., N. C.
Transcontinental Gas Pipe Line Corp.	219	30	Ala., Ga., S. C., N. C., Va.
Union Gas Company of Canada	180	—	Dawn Storage field to Hamilton
United Natural Gas Company	50	12	Elk County to Jefferson County, Pennsylvania
Utah Natural Gas Company	40	16	Orem to Salt Lake City, Utah
Virginia Natural Gas Company	153	—	Buckingham to Richmond and Portsmouth, Va.
Warren Petroleum	54	4-30	Lea County, New Mexico
Westcoast Transmission Co., Ltd.	650	30	Peace River area, Alberta, to U. S.-Canadian border

MARVEL INVERSE OILER-

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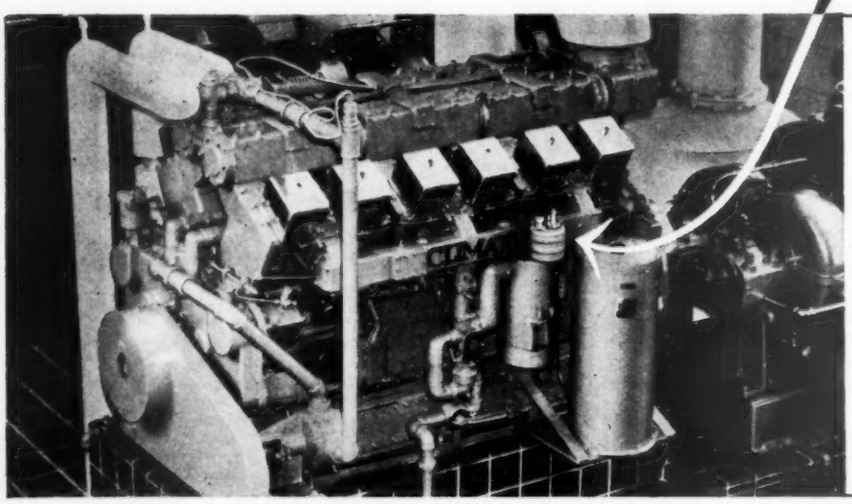
Engine manufacturers think so highly of the Marvel Inverse Oiler they have incorporated it as a vital unit in their engines' lubrication systems.

They have found that engines, equipped with Marvel Inverse Oilers, can be depended upon to give quick acceleration to save trip time . . . keep operating costs to a minimum . . . guarantee hours of continuous performance . . . keep "down-time" low by extending periods between overhauls.

The famous Climax Engines, one of which is pictured below, is an example. A truly fine performer, it is equipped with a Marvel Inverse Oiler for Marvel Mystery Oil—finest performing lubricant of all.

The Marvel Inverse Oiler feeds Marvel Mystery Oil in exact proportion to engine speed and load . . . properly lubricating valves and guides, preventing wear and sticking. Keeps upper piston rings free in their grooves . . . retards ring flutter . . . and cushions ring pounding which can result in ring breakages. Remember, it is the *oil* which must do these things and only Marvel Mystery Oil is blended for this purpose and for this oiler.



The Marvel Inverse Oiler

is an integral part of the Climax 12 cylinder, 171 H.P., 600 RPM GAS ENGINE. Operating off the intake manifold, this completely automatic Oiler feeds Marvel Mystery Oil exactly in proportion to engine loads . . . gives direct protection to the all-important upper cylinder areas.

This Chart shows the proper setting for constant load engines

BRAKE H. P. AT BELT	NAT. GAS CU. FT. PER HOUR	BUTANE GALLONS PER HOUR	GASOLINE GALLONS PER HOUR	M. M. OIL DROPS PER MIN.	M. M. OIL HOURS PER QUART
10	115.	1.07	1.12	4	228
15	172.5	1.60	1.68	6	152
20	230.	2.14	2.24	8	114
25	287.5	2.67	2.80	10	91
30	345.	3.21	3.36	12	76
35	402.5	3.74	3.92	14	65
40	460.	4.28	4.48	16	57
45	517.5	4.81	5.04	18	50
50	575.	5.35	5.60	20	45
60	690.	6.42	6.72	24	38
70	805.	7.49	7.84	28	32
80	920.	8.56	8.96	32	28
90	1035.	9.63	10.08	36	25
100	1150.	10.70	11.20	40	22
120	1380.	12.84	13.44	48	19
140	1610.	14.98	15.68	56	17
160	1840.	17.12	17.92	64	14
180	2070.	19.26	20.16	72	12
200	2300.	21.40	22.40	80	11
225	2587.5	24.00	25.20	90	10
250	2875.	26.75	28.00	100	9
275	3162.5	29.42	31.10	110	8
300	3450.	32.10	33.60	120	7

Chart shows total oil consumption

EXAMPLE:—If you use 805 cu. ft. of dry gas, 7.49 gallons of butane or 7.84 gallons of gasoline, your H.P. is about 70, so adjust oiler to feed 28 drops per minute. You will then receive about 32 hours per quart of MARVEL MYSTERY OIL.

If engine load increases after setting for normal load, oiler will automatically increase its feed, decreasing when load is lessened.

To determine drop count per oiler when more than one is used on an engine—divide recommended drop count by number of oilers.

NOTE: Guarantee on oiler is void if any other oil than MARVEL MYSTERY OIL is used. Some *engines* also carry this guarantee policy.

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Slate quarry storage lowers cost per barrel, increases safety, and reduces maintenance and repair

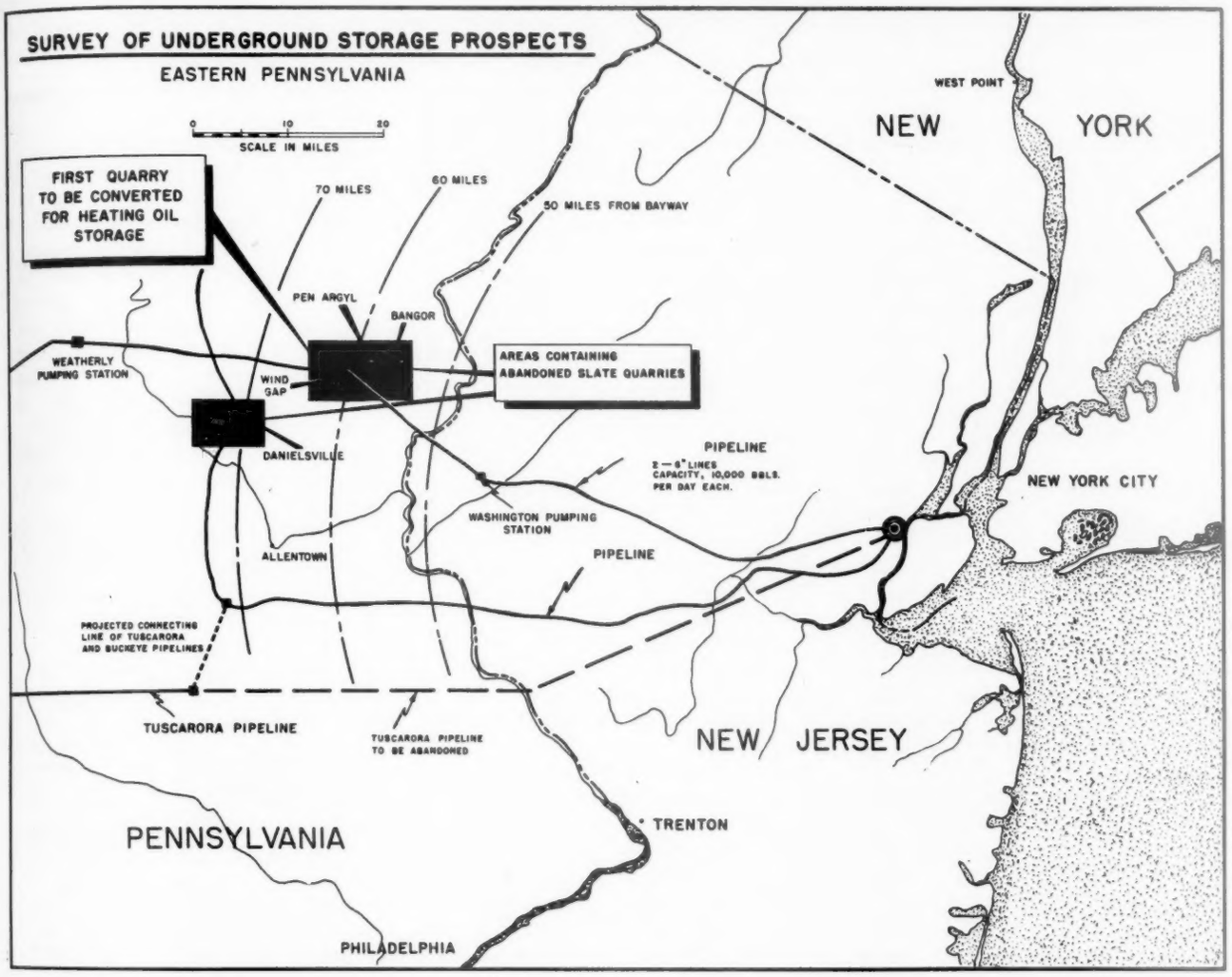


FIG. 1. Summer reservoir for heating oil from Bayway Refinery 68 miles away will service eastern markets during high winter demands.

Heating Oil Goes Underground

Kenneth J. Nuber
Esso Standard Oil Company
Bayway, New Jersey

THE world's largest oil storage "tank" has been put into service at Wind Gap, Pennsylvania, by the Esso Standard Oil Company. On September 8, finished heating oil was pumped from the Bayway Refinery, Linden, New Jersey, 68 miles west into an abandoned slate quarry in eastern Pennsylvania. Conversion of this open pit into a 1,000,000 bbl reservoir for heating oil marks the first such attempt in this country.

EXCLUSIVE

No mechanical means have been used to seal the numerous cracks in the slate walls. Instead, the hydrostatic head of water in the ground surrounding the pit is utilized to prevent oil from escaping. To keep out air-borne contamination and to reduce evaporation losses, a steel floating roof was constructed to cover the 1⅓ acre opening.

Heating oil, processed at the Bayway Refinery, will be stored in the reservoir during the summer. The oil will be returned for distribution in the New York Metropolitan area during the winter period of peak demand. Operation of the reservoir at 20 per cent of capacity last fall proved successful to date. Throughout the winter 160,000 bbl of oil will be kept in the pit, serving as a pilot plant run to demonstrate the practicability of full scale operation.

Ground Water Used to Seal Cavern

In this application, quarry storage has indicated these salient features:

1. **Lower initial investment per bbl.**
2. **Maximum safety, and**
3. **Potentially lower operating costs due to minimum repair and maintenance.**

An investigation was started in 1952 to determine the feasibility of using natural underground reservoirs in place of expensive steel tanks for seasonally storing heating oil. This study was limited initially to the general vicinity of Metropolitan New York where the largest seasonal storage requirements exist. In the ensuing literaature, map, and field surveys, particular attention was given to areas adjacent to existing pipe lines or deep water terminals.

Two types of reservoirs were considered: (a) Cavities impermeable to oil or those that could be made oil tight, and (b) permeable cavities that could be sealed using the surrounding water table. No satisfactory "tight" cavities were found. As for permeable reservoirs, the search uncovered many abandoned iron, copper, and zinc mines; quarries in slate, limestone, cement rock, and trap rocks, and a large number of clay pits. The metal mines were eliminated at this point because it was expected that the metal ores would have an adverse effect on the quality of the heating oil. Most of the other pits were also rejected because of their poor location, the local topography, or their small size.

One group of slate quarries in eastern Pennsylvania, 70 miles inland, looked promising (shaded are—Fig. 1). Located in this 5-mile wide belt are many abandoned quarries of appreciable size ranging up to 500 ft on a side and 700 ft deep. In addition to their large capacities, accelerated storage tests in the laboratory indicated that the slate has no effect on heating oil quality.

The principles by which the storage of oil in an abandoned mine or quarry is accomplished without the aid of a lining, are based primarily on the water table. The water table can be defined as the upper limit of that portion of the ground wholly saturated with water. Maintaining the proper level of the stored oil relative to the water table in the surrounding formation will prevent oil escaping from the pit.

With the exception of desert regions where little rain falls, the ground everywhere has a water table. In most areas of average rainfall the water table lies near the surface, or at relatively shallow depths. The water table is not flat and generally slopes in the same direction as the surface topography. The waters below the table are continually in motion, moving gradually from the high to low terrain.

All rock formations including sandstone, shale, slate, limestone, and granite are permeable to some extent to the percolating rain water. In the case of slate, although very little water moves through the rock itself, water does move through the joint planes and shear zones present in the rock formations. Naturally, the water table will vary with the seasonal change in rainfall.

In general then, the area of the rock formation surrounding a quarry below the water table is a continuous zone of water. At any point on the wall of the pit in this zone, a pressure exists corresponding to the height of water above that point. As oil is lighter than water, the same height of oil will exert a lower pressure than the water. Therefore, as long as the level of oil in the cavity is kept below the water table, water will leak in and no oil can leak out. The water seepage must be removed by pumps regularly to keep the oil level below the water table at all times. To demonstrate the workability of this principal, a model was constructed of lucite plastic complete with miniature circulating pump. This model proved invaluable in demonstrating to those people living in the area of the quarries picked for future oil reservoirs that the idea really works.

Each abandoned quarry site was checked to determine those which were the most desirable. Topographical maps and aerial photographs were used to study each site in relation to the surrounding areas.

Specific quarries were chosen on the basis of the following characteristics:

1. **Remote from working quarries or populated areas,**
2. **Large potential capacity,**
3. **Relatively deep,**
4. **Situated in low, level ground, and**
5. **Adequate source of water.**

The last two considerations are of primary importance where the permeable nature of the faulted rock, such as these slate formations, makes it necessary to use the ground water as a sealant. Low, level ground, in general, has a relatively high and stable water table level allowing the major portion of the total quarry volume to be used for oil storage. Conversely, where the quarries are situated on a hillside or high ground, the water table is usually too low or undependable to assure a safe seal.

An adequate source of water is also necessary if water displacement is used to maintain a constant total liquid height in the quarry. The water displacement method was chosen because it allows easy removal of all the oil from the irregularly shaped bottom of the pit, prevents the possible collapse of the walls, which might occur if they were unsupported by fluid, and permits the use of a floating roof. A second nearby quarry that could serve as an ideal source of water was found in many cases.

After screening each pit, options to purchase were obtained on additional sites. Accurate soundings were taken of these pits in order to determine their real capacity. The soundings were made at 25-ft intervals over the entire water area. Based on these soundings, their total potential oil capacity is estimated at 360,000,000 gal.

Alpha quarry, near Wind Gap, Pennsylvania (see Fig. 2) was chosen as the

The Author

Kenneth J. Nuber has been working with underground storage with Esso Standard for the past two years. He joined Esso in 1950 and spent 1½ years with distillation coking and thermal cracking.

Nuber is a chemical engineer graduate of the University of Cincinnati.

first site to be developed because of its size and proximity to an existing pipe line. Also, a second quarry (Acme) which serves as the water reservoir, is located just 75 ft away. The two quarries lie just 1500 ft from two 6-in. pipe lines connecting directly to the Bayway Refinery. The quarry itself is 250 by 350 ft and is 225 ft deep at the deepest point. Fig. 2 shows Alpha prior to any construction and filled with water to the natural ground water level.

Construction began in March, 1954, with the clearing of the site. Bulldozers leveled all brush and trees for approximately 100 ft in every direction. Simultaneously the piles of waste slate around the sides of the quarry were graded back to a 45-deg slope. More than 28,000 cu yd of this waste material were removed to prevent future rock slides. Portable pumps lowered the water level in Alpha some 30 ft to what is now the operating level, so that work could begin on the pump platform and the floating roof.

Location of the major pumping facilities installed at the site are shown in Fig. 3. They include the oil and water pumps, control house, power transformer, and necessary tie-in lines for water and oil. The 5000-bbl steel tank at the site is used periodically for calibrating the oil delivery meter. It can also be used for settling the oil-water emulsion if it becomes necessary to pump out the last few inches of oil. In addition to the positive displacement oil meter, remote reading float type level gages indicate the level of the oil-water interface in the quarry. Two 400-gpm submersible deep well pumps were suspended at the deepest spot in the quarry from a cantilever platform anchored into solid rock 15 ft above the roof. When the reservoir is operating, these pumps continually remove water from the bottom of the pit and discharge it into water quarry, Acme.

FIG. 2. Alpha quarry as first seen by engineers was a vast, natural and inexpensive storage tank. Water level was lowered 30 ft to operating level.

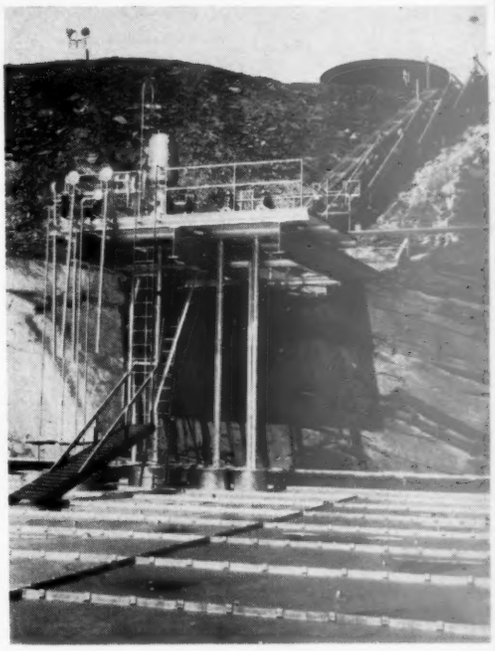
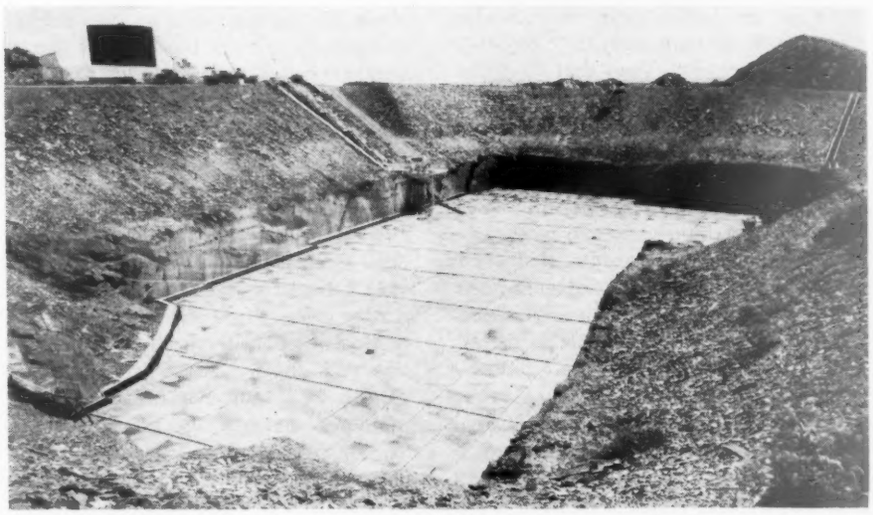


FIG. 3. Major oil and water pumping facilities at the quarry consist of two 400-gpm submersible deep well pumps suspended from cantilever platform.

FIG. 4. Steel floating roof, 60,000 sq ft of 240 pontoon sections, 32 ft by 7 ft-6 in., weighing 3 tons each protects oil from contaminants, evaporation, and fire.



Stream Pollution Prevented

Precautions have also been taken to prevent any pollution of the small stream flowing from Acme should oil be accidentally carried over with the water. A floating steel baffle, 40 ft square and 4 ft high, surrounds the water discharge line. A steel skimmer was also placed at the overflow to the stream as an added safeguard. A 400-gpm deepwell submersible pump and cantilever platform are also located at Acme for returning water to the oil reservoir when the heating oil is pumped back to Bayway.

The major cost item is a steel floating roof (see Fig. 4) constructed to cover the entire 60,000 sq ft of opening. It is made up of 240 separate pon-

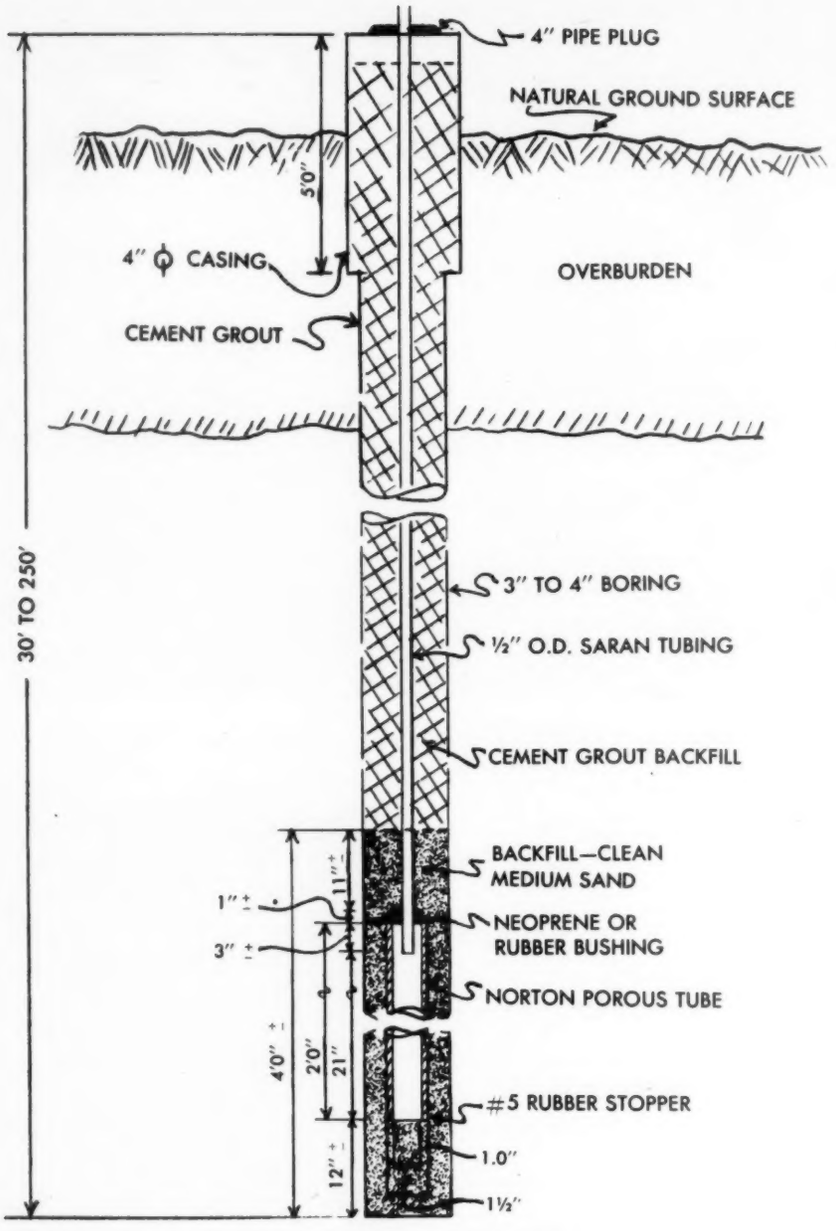


FIG. 5. Detail of piezometers used around quarry to check water table, which prevents water from leaking out.

toon sections each measuring 7½ ft wide, 32 ft long. Each pontoon is provided with a 2-in. drain to pass surface drainage and rain water, and is designed with enough buoyancy to carry the maximum snow load that could be expected in this area. The 3-ton sections were fabricated in the shop, shipped to the site by truck, and lowered directly from the truck to the water some 65 ft below ground level. The individual pontoons are held together by heavy metal clamps. The clamps are forced over the raised lip of two adjacent pontoons at 1-ft intervals and tack-welded in place. The clamps can be loosened using only a hammer. This was done so that any section can be removed for repair and replaced without exposing the oil in the pit to the flame from a cutting or welding torch.

Steel Cavern Roof Built

To partially compensate for the irregular outline of the quarry, a steel shelf of varying width was erected completely around the edge of the pit and anchored securely to the rock wall. The larger irregular areas are fitted with wedge-shaped pontoons fabricated at the site.

To complete the seal a neoprene fabric 1/16-in. thick, is fastened securely between the steel shelf and the edge of the roof. Enough slack is provided to allow the roof to move vertically about 3 ft. To keep the 700 tons of floating steel from shifting position under high winds, 8 spring-loaded cables, two anchored into each wall, maintain a positive tension on the roof in all directions. While keeping the roof in place, they do not impede its movement in a vertical direction.

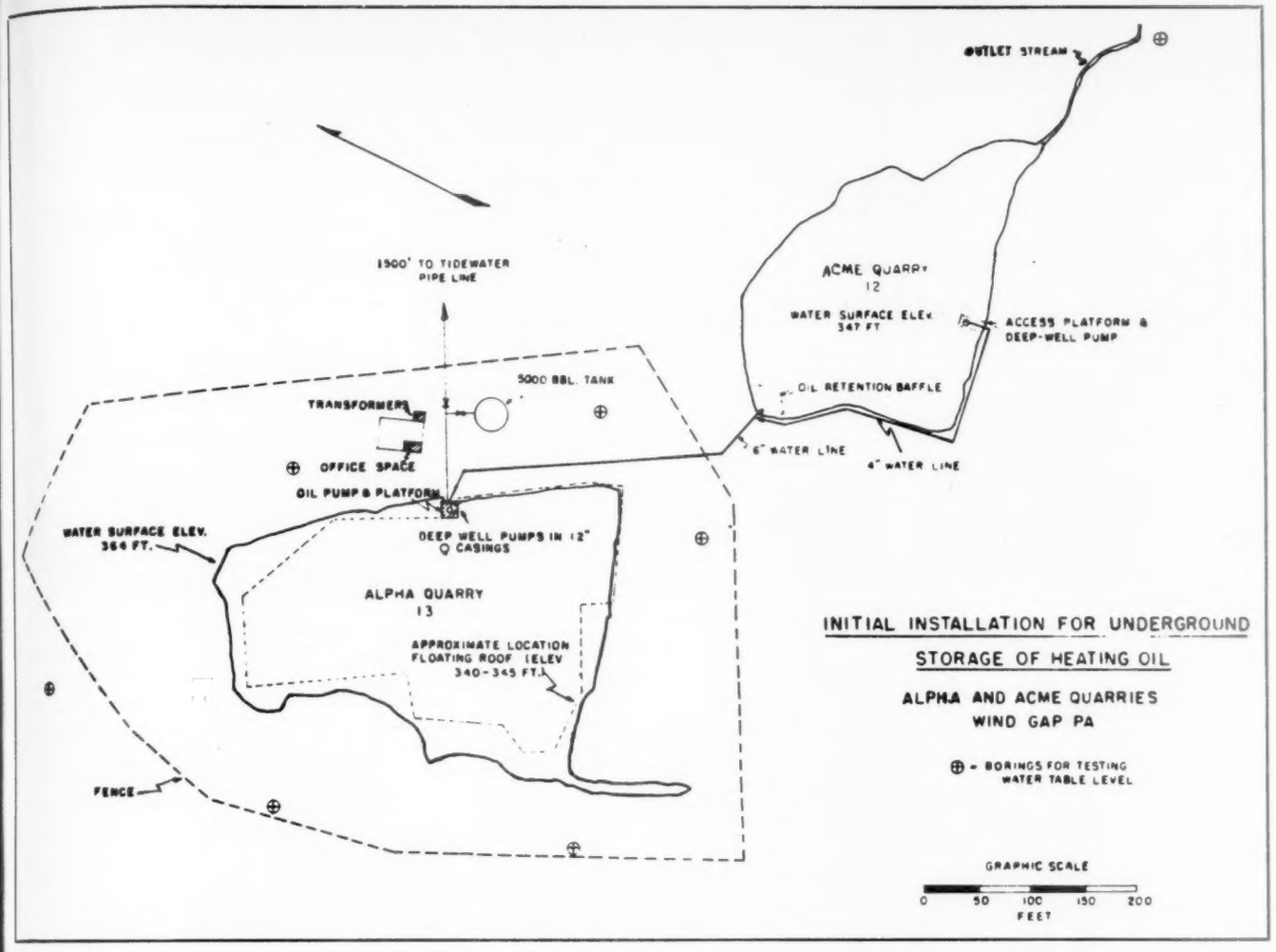
The protection offered by the steel roof will essentially eliminate any remote possibility of the heating oil catching fire. In addition, the roof will protect the finished oil from air-borne contaminants, wild life, and direct sunlight. Lab tests have indicated degradation of heating oil if the oil is exposed to direct sunlight. Also, the roof will reduce losses from evaporation to essentially zero. If no covering were provided, evaporation losses from the large surface of the pit might be as much as 20,000 bbl over a 6-month period.

In operation, oil is pumped from Bayway Refinery to the reservoir during the summer months through a 6-in. pipe line at a rate of 5400 bbl per day. It will be returned during the 4 or 5 month winter period of peak demand at 8500 bbl per day. As the pipe line is limited to a maximum pressure, the return pumping rate is greater due to the 700 ft higher elevation at Wind Gap. When oil is pumped into the reservoir, the water displaced by the oil, as well as the water seepage through the walls, is pumped over to the adjacent Acme quarry. The resulting overflow from Acme empties into a small stream which eventually flows into the Delaware River. The seepage into Alpha varies from about 100 gpm in the dry summer months up to 300 gpm in the spring. When the oil is pumped from Alpha back to the refinery, in addition to the natural seepage, make-up water is supplied from Acme always to maintain the same total liquid level in Alpha.

To insure a positive ground water pressure on the walls of the oil quarry at all times, this level is kept approximately 20 ft below the average water table level. This allows a wide margin of safety since the maximum variation in the water table in this area is only 3 to 5 ft even during prolonged periods of dry weather.

Watch Water Table Level

To determine the height of the water table and its variation with the changing seasons, piezometers were installed around the oil quarry 6 months before construction was started (see Fig. 5). At 7 carefully chosen points around the pit, 3-in. diam wells were drilled to depths from 150 to 250 ft. After the bottoms of the holes were cemented securely, a ½-in. saran tubing connected to a 2-ft porous tube was lowered to the bottom and covered with fine sand to a height of 4 or 5 ft. More cement grout was then used to seal off this section containing the porous tube. On several occasions, two or three piezometers were installed at the same point but to different depths. The ground water filtering in through



the rock sand and porous tube rises inside the ½-in. tube; the total height of water in the tube is equivalent to the water pressure in the rock formation at the bottom of the tube. A coaxial cable, connected to a small battery, is lowered inside the ½-in. saran tube. When the bared end of the cable hits the water, the completed electric circuit is indicated on an ammeter. The length of cable needed to reach the water level in the tube is used as the distance from the top of the tube to the water table.

Piezometer

For more than six months prior to construction, each piezometer was read every two weeks to determine the stability of the water table. All during construction the piezometers were read daily to learn to what extent the lowering of the water in the pit would lower the water table. A gradual drop in the piezometer levels at the edges of the pit during this time indicated a definite "cone of depression" had formed. The readings will be continued all during the oil storage period in order to assure that there is sufficient water table to prevent any oil leakage.

In general underground storage in open mines or pits is best adapted to situations where large volumes of a petroleum product are handled at a low turnover rate, such as seasonal storage. As the roof represents a large portion of the investment, it is desirable to convert only deep pits having a low area per volume ratio. Based on this design, open pits less than 100 ft deep are not likely to be attractive.

It is also important to control at least the mineral rights to 30 or 40 acres surrounding a potential storage quarry. This is necessary to prevent any future excavation nearby that might disturb the water table and cause oil leakage. Therefore, in areas known to contain valuable minerals, the high cost of the mineral rights necessarily will limit storage to abandoned or depleted reservoirs.

Storage Cost, 50 Cents Per Bbl

The investment required for converting Alpha quarry into a 1,000,000-bbl oil reservoir totaled approximately $500,000, or 50 cents per bbl of storage capacity. This comparatively low investment for Alpha was possible only because an existing pipe line was available to move the oil to and from the pit. Development of large volumes of storage in other quarries now under study are expected to show even greater savings in investment, however. Substantial savings in annual operating costs are also anticipated, although initial operating costs for Alpha are expected to be slightly higher than for steel tankage. Ultimately, annual operating savings should accrue from less repair and maintenance costs and lower depreciation on the smaller investment required. There is also the possibility that the operation can be made completely automatic, thus effecting further savings in operating manpower.

As a result of the apparent successful operation of Alpha quarry, it is evident that seasonal storage in natural reservoirs can offer large savings in both initial investment and annual operating costs. From studies now underway, it is believed that abandoned mines may eventually be adapted to the storage of other petroleum products such as fuel oil, kerosine, and crude oil. ★

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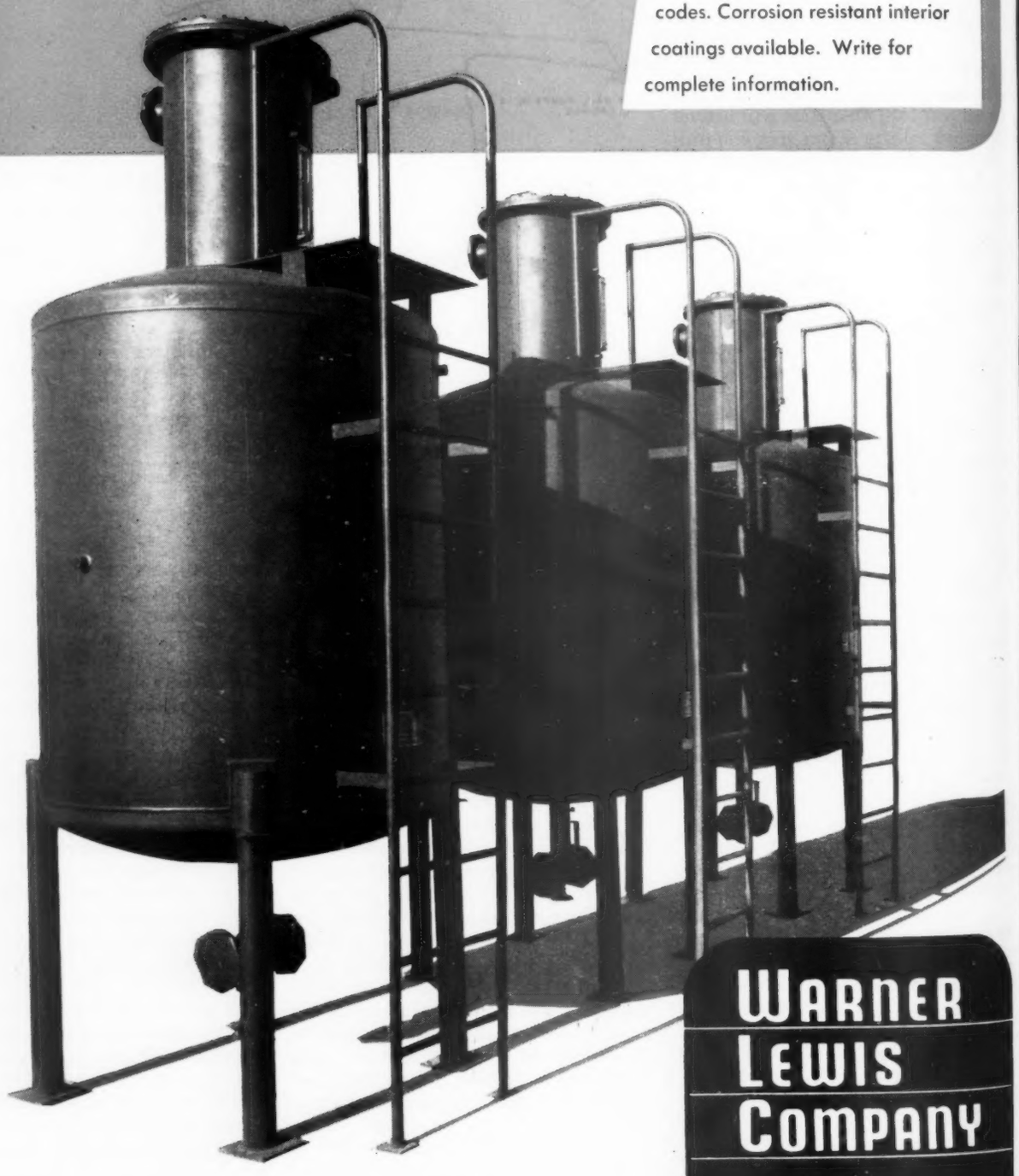


WARNER LEWIS COMPANY

DIVISION OF FRAM CORPORATION

BOX 3096 • TULSA, OKLAHOMA

Here are some **important facts** you should know about

Venting Atmospheric Pressure Tanks

H. C. Packard
Secretary, Loss Control Committee,
Shell Oil Company,
New York City

ACCORDING TO FUNK AND WAGNALLS, a *vent* is "an opening, commonly small, for the passage of something, as air; hence, an outlet of any kind;" whereas *to vent* is defined as "to permit to escape at a vent, as a gas" and "to relieve, as by giving vent to something."

In order to appreciate the need for and function of a vent on a petroleum tank operating at substantially atmospheric pressure, it is necessary to understand the so-called *filling, emptying* and *breathing* cycles in tank operation. For various reasons a tank usually is not *completely* filled with liquid. The space above the liquid and below the tank roof is called the vapor space. This space is occupied completely by some combination of air and hydrocarbon vapors, the ratio between the two varying within the limits of pure air and a completely saturated mixture, dependent upon several factors such as vapor pressure of the stored liquid, temperatures, and so on.[1]

In any event though, the air-vapor mixture in tank operation is subject to *displacement* through tank filling, *replacement* by air during tank emptying, and *expansion* or *contraction* during tank breathing.

During tank filling, the air-vapor mixture is displaced volumetrically at a rate approximating the volume of incoming liquid. During tank emptying, fresh air is drawn into the tank at a rate volumetrically approximating that of the outgoing liquid.

While both of these basic statements are true to a major extent, they are somewhat over-simplified in the sense that the stated straight volumetric relationships are subject to some minor variation due to the concurrent effects on the air-vapor volume of any natural evaporation process taking place, plus temperature change.[1] Obviously, in both cases, a reasonably unimpeded compensating or offsetting flow of air-vapor mixture is required to prevent tank bursting or collapse.

During tank breathing, the air-vapor mixture expands or contracts as the temperature rises or falls. As the temperature rises during the day, the air-vapor volume increases and requires an outlet prior to building up to the tank-bursting point. As the temperature falls during the night, or during weather changes in the day, the air-vapor volume decreases and requires replacement by drawing in fresh air before reaching the tank-collapsing point.

The rate of volumetric change of the air-vapor mixture accompanying the temperature change is several times greater than the corresponding volumetric change for most stored liquids, and so the requirement for a means of relief is second only to the corresponding requirements for tank filling and emptying.

The foregoing demonstrates the principles of the usual needs for tank pressure or vacuum relief requirements, short of emergencies. Measures for providing relief usually take the form of one or more openings in the tank roof, as will be discussed.

Early Vent Types

The first vents were simply openings, round or rectangular, in the tank roof, sometimes with weather hoods over them. Such *open* vents provided for air-vapor outward and air flow inward, consistent with maintenance of substantially atmospheric pressure equilibrium between the inside and outside of the tank. Two such open vents on a single tank appeared to function better, or perhaps more quickly, than only one vent. As need for handling an increasing proportion of liquids with higher volatility characteristics entered the picture, however, it was noticed also that *evaporation losses* seemed to be quite high, evidently well beyond a rate consistent with the increase in volatility alone.

At this point, it was thought advisable to retard somewhat the unimpeded flow of air into and air-vapor mixture out of a tank. Early steps in this direction were to close all openings in the tank roof. Manheads were covered by plates bolted over them, but it was still necessary to provide for routine or quick tank pressure or vacuum relief.

So, other openings, usually the gaging and sampling hatch openings, were provided with hinged covers. As breathing pressure built up inside the tank, it would raise these covers and provide its own relief by venting. As the tanks were filled or emptied, it was customary to open the hatch covers for the duration of the operation. Provision for tank breathing vacuum relief was taken care of by propping the hatch covers into a partially open position. This last mentioned practice has had some unfortunate carry-overs into current usage in much more modern tank venting equipment.

EXCLUSIVE

The Author

H. C. Packard is chief analyst in Shell Oil Company's products pipe line department and secretary of Shell's loss control committee. He attended Nazareth Hall Military Academy in Pennsylvania before joining Shell in 1928 as a clerk in the St. Louis office.

After serving in various positions in the crude oil department, Packard was transferred to the head office in New York in 1940. He was named to his present position in 1946.

Packard is chairman of the API committee on crude oil measurements. He is also chairman of the tank calibration section of ASTM, D2-Division II, and of other industry groups. Besides writing many technical papers on crude oil and product measurement, Packard is author of a book: *Tank Volume Determination—Its Theory and Practice*, published in 1946.

Conservation Vent Development

Growing appreciation of the economic desirability of providing for maximum petroleum tank hydrocarbon vapor conservation led to further developments in tank vent design, accompanying progressive changes in design and maintenance of the tanks themselves.

It was recognized that maintenance of some degree of pressure restraint against the outward flow of air-vapor mixture accompanying normal tank out-breathing would be a definite step toward vapor conservation. It also was realized for safety reasons that the maximum pressure that could be applied in this manner would have to be somewhat less than the minimum pressure that might cause tank bursting.

In addition, any device used would have to provide for relief of the maximum permitted internal condition of vacuum somewhat before reaching the minimum point that might result in tank collapse. Then, too, it was desirable for the venting device to accomplish these several objectives automatically. This would eliminate the need for manual attention other than that of normal inspection and maintenance.

Resulting developments were in the fields of both tanks and vents. Most tanks were constructed so as to be gas-tight as well as liquid-tight with two exceptions: First, provision was made for roof openings on which the new and especially designed relief vents could be mounted; second, a deliberately weak portion of a seam was provided in the roof to shell connection or in the roof to encourage tank structural failure at a known location, in case the relief vent failed to operate quickly or sufficiently.[2]

Vents were constructed in several designs, but most of them had these basic characteristics provided. Pressure relief was by means of a plate, usually circular, known as a pallet or seat with a shape and area such as to allow closing off the direct and usually vertical opening into the tank on which the plate rested.

Some plates were and are guided by rising and falling around a fixed shaft through their center, while others depend primarily on preventing horizontal movement by built-in vertical restrictive contacts with their outer edges through the vertical opening in which they rise and fall. Some plates are of low sparking potential metal, some of other composition, and some of a combination of metal backing and composition facing.

Details of seating contact design vary too; some are flat, some rounded, and some approach a knife-edge.[3] Obviously, when seated, efficiency requires a snug fit all around the outer under-surface of the plate. With this basic concept, pressure beyond atmospheric builds up to the weight of the plate and, as pressure increases further, raises the plate and maintains it in a raised position until pressure is relieved downward to the level just below that required to lift the plates again and provide venting.

This cycle repeats itself as necessary to prevent pressure build-up beyond atmospheric plus the weight of the plate, which latter, therefore, is shown to be the limit control factor in the device. Vacuum relief is provided by a similar device, except that the connected piping through the tank roof and for the vent is rearranged so that the outer or atmospheric pressure is presented to the lifting face of the sealing plate, the weight of which in this case equals the maximum unit vacuum to be safely permitted.

In modern practice, for most of the larger cone roof tanks, vacuum relief is generally provided at one-quarter to one-half ounce psi and the relief settings, *i.e.*, seat plate weights, established accordingly.

For pressure relief, the settings vary, primarily decreasing as tank diameters increase, especially for cone roof tanks, but settings may range from one-half up to several ounces psi, consistent with the specific tank design and size limitations in question.

As a general rule of thumb, it has been stated reliably for such type tanks that a restraining pressure of one ounce should yield about 7 per cent savings or reduction of total air-vapor mixture loss that would occur by normal out-breathing at atmospheric pressure.[1]

Higher restraining pressure settings, according to the same authority, yield progressively further but lesser unit rate reductions until reaching a pressure of 2½ lb, at which point all out-breathing loss should be prevented. Such a pressure relief setting, however, is far beyond the safety limit for tanks not specifically designed as pressure vessels.

Vents and Conservation Types of Tank Roofs

A variation in the dual use, just described, of tank vents as both tank vapor conservation and tank safety devices has accompanied the development in recent years of the expansible volume vapor space tanks. Several variations of designs for such tanks are commercially available,[4] but all of this particular type have in common some means for retaining in the tank all or at least most of the expanded air-vapor mixture that otherwise would be vented through normal tank out-breathing cycles.

Basically, the means for accomplishing this is built around the concept of expanding the vapor space capacity of the tank as a variable consistent with current requirements rather than increasing the restraining pressure within the limits of an unchanged capacity.

Mechanically, such tank designs provide for a raising and lowering of the tank roof, or an accumulator bag for vapor expansion and contraction under a fixed roof structure of special design or in a special separate structure. In either case, it always is desirable to retain vapor-tightness under all conditions of the variable vapor capacity range. For these designs, however, as the upper limit of the variable vapor capacity range is reached either through excessive vapor breathing expansion or more commonly during tank filling, it is necessary for tank safety to provide for pressure relief in the same manner previously described.

It also is currently rather common practice to vapor-manifold other cone roof tanks with these expansible volume vapor space tanks. This allows the user to take maximum practical advantage of various inherent characteristics of such a method of tank operation.

In these cases, all tanks in the system usually are equipped with their own vents. The pressure relief setting on the conservation-type tank is then very slightly below that of the setting for the other tanks in the system. This, then, provides pressure drive for expanded vapors in the cone roof tanks into the conservation tank before venting to the outside atmosphere can take place, if it (within tank safety limits) needs to take place at all.

A Link in the Chain

It is obvious from the foregoing that pressure/vacuum relief vents are a very integral part of modern day tank operations. Normally, the cost of vents is a relatively small portion of the total cost of a tank and its appurtenances.

For this and other reasons, it sometimes happens that tank vent size and type requirements as well as inspection and maintenance needs during operation are not given the attention really merited. **This is a mistake that can have very costly and sometimes disastrous results.** The vent is an important link in the total chain of vapor conservation and tank safety requirements, and it will be remembered that no chain is stronger than its weakest link. This places a considerable and significant responsibilty on the vent manufacturers, as well as on the tank design, construction, and maintenance engineers.

Development of Liquid Seal Type Vents

It will have been noted that the vents so far described have been of a mechanical type, and most of those in use today are of the mechanical type. It long has been known, however, that it is possible in principle to use a liquid seal instead of the mechanically seated seal.

Indeed, one rather large user years ago developed a design of his own, and reported fair success, particularly with the central separated breather bag type of tank vapor conservation.

Otherwise, however, it has not been until quite recently that liquid seal type vents have been offered commercially. At least two such designs have received attention for consideration by industry,[5] and one in particular has been widely publicized, together with claims of very high success in tank vapor loss reduction.

The writer has had opportunity of only very limited observation of the operation of the three liquid seal type vents mentioned and so cannot yet make any positive statements of value as to relative merits under practical operating conditions.

Theoretically, however, the following may be mentioned. Where certain types of mechanically seating seals may be inclined to hunt or chatter, the liquid seal types should be quick, positive, and smooth in operation. Maintenance at proper density of the sealing liquid may be a problem from the viewpoint of preventing mixture with water of condensation or hydrocarbon vapors; also, evaporation and freezing must be prevented and means included to insure not blowing out the sealing liquid.

On the other hand, some of the mechanical types are subject to rusting or corrosion and may stick at times due to freezing of water of condensation and other causes. So it is seen that both types may have both advantages and disadvantages. Nevertheless, progress has been made in both directions and we may be sure that progress will continue in the future.

Use of Flame Arrestors With Vents

The primary purpose here is not to debate the necessity for, or the merits or demerits of, the use of flame arrestors, but, because of the marked differences of opinion on the matter, rather only to mention those aspects directly bearing on vents where flame arrestors are used as a supplement to vents.

First, then, underwriters and municipal and other regulatory authorities have specified the use of flame arrestors on tanks under various specified conditions, although in recent years some relaxation in these requirements has become apparent.

Second, conferences of representatives of petroleum industry users, regarded as competent to render expert opinions, have stated that use of adequate flame arrestors with pressure/vacuum relief vents reduces the vent capacity by as much as two-thirds in the given case, with the obvious effect of considerably increased costs for both vents and flame arrestors in the fields of acquisition, installation, and maintenance.

Third, some of these same industry sources in various individual cases have arrived at independent decisions tending against specifying use of flame arrestors so far as technical and economic reasons only are concerned.

Therefore, in the individual case, it appears that for other than compliance with applicable regulations and having at hand data and opinions as just referred to, the decision to use or not to use flame arrestors for given conditions of type of operations and locality must be taken on a calculated risk basis.

Vent Size and Use Applications

Recommendations in this respect are given quite competently by widely recognized industry association publications specifically on this subject. Outstandingly typical of these are recent publications of API and NFPA.

The American Petroleum Institute (API) publication, No. R.P. 2000, is titled "Guide for Tank Venting and Recommended Procedure for Testing Venting Devices for Low/Pressure Above Ground Storage Tanks for Petroleum and Petroleum Products," dated October, 1952. This publication is reproduced by permission in Appendix 1.

The National Fire Protection Association (NFPA) publication referred to, No. 30-L, is titled "Suggested Ordinance for the Storage, Handling and Use of Flammable Liquids," dated May, 1954. Section 208 on "Vents" also gives information pertinent to the subject and quotes requirements for pressure relief capacity of vents based on the American Petroleum Institute sources above. Other sections of this same publication, such as No. 215-01 on "Vents for Tank Connections for Tanks Underground or in Buildings," also give valuable information on the matter.

References

(1) "Evaporation Loss of Petroleum from Storage Tanks"—Papers I and II, API Symposium, November, 1952.

(2) Tank specifications by API and specification literature offered by companies such as C.B.&I., General-American, Graver, Hammond, National, and Parkersburg.

(3) Typical specification literature offered by B.S.&B., Johnson & Jennings, Shand & Jurs, and Varec.

(4) Typical offerings are by C.B.&I., GATX, Graver, and Hammond.

(5) "Conservent" and "Burp": Trademarks.

Appendix I

API Guide for Tank Venting and Recommended Procedure for Testing Venting Devices for Low-Pressure Aboveground Storage Tanks for Petroleum and Petroleum Products

1.0 Scope

This guide applies to aboveground petroleum storage tanks designed to operate essentially at atmospheric pressure.*

Venting requirements for the following conditions are set forth:

A. Outbreathing due to maximum inflow of oil into tanks and due to maximum evaporation caused by such inflow.
B. Outbreathing due to expansion and evaporation which result from maximum increase in atmospheric temperature (thermal breathing).
C. Outbreathing due to abnormal or emergency conditions, such as an exposure fire.
D. Inbreathing due to maximum outflow of oil from tank.
E. Inbreathing due to contraction of vapors resulting from maximum decrease in atmospheric temperatures.

2.0 Normal Venting Capacity Requirements

2.1 *For Outbreathing (pressure relief)*

2.11 Requirement due to oil movement into tank and resulting evaporation should be equivalent to 600 cu ft of air per hour for each 100 bbl per hour of maximum filling rate for oils with flash point of 100 F and above.

2.12 Requirement due to oil movement into tank and resulting evaporation should be equivalent to 1200 cu ft of air per hour for each 100 bbl per hour of maximum tank filling rate for oils with flash point below 100 F.

2.13 Requirement due to thermal outbreathing, including thermal evaporation, for the given tank capacity for oils with flash point 100 F and above, should be that shown in column 3 of Table 1.

2.14 Requirement due to thermal outbreathing, including thermal evaporation, for the given tank capacity for oils with flash point below 100 F, should be that shown in column 4 of Table 1.

Notes for Table 1

For tanks with more than 20,000-bbl capacity, the requirements for the vacuum condition are very close to the theoretically computed value of 2 cu ft of air per hour per square foot of total shell and roof area. For tanks of less than 20,000-bbl capacity, the thermal inbreathing requirement for the vacuum condition has been limited to 1 cu ft of air per hour for each barrel of tank capacity. This is substantially equivalent to a mean rate of vapor-space-temperature change of 100 F per hour.

The required outbreathing capacity for stocks with a flash point at or above 100 F has been assumed as 60 per cent of the required inbreathing capacity, as the tank-roof and shell temperatures cannot rise as rapidly under any conditions as they can drop during a sudden cold rain.

For stocks with a flash point below 100 F the thermal pressure-venting requirements have been made equal to the vacuum requirements, in order to allow for vaporization at the liquid surface and the higher specific gravity of the tank vapors.

2.2 *For Inbreathing (vacuum relief)*

2.21 Requirement due to oil movement out of tank should be equivalent to 560 cu ft of air per hour for each 100 bbl per hour of maximum tank emptying rate, including gravity flow rate to other tanks, for oils of any flash point.

2.22 Requirement due to thermal inbreathing for the given tank capacity for oils of any flash point should be that shown in column 2 of Table 1.

2.3 *Total Normal Venting Capacity*

The total normal venting capacity should be the sum of the capacity required for inflow or outflow plus the capacity for thermal inbreathing or outbreathing, as determined from Table 1. This capacity should be obtained without exceeding an operating pressure or vacuum which may be applied to the tank regularly and repeatedly without causing injury or permanent deformation.

3.0 Types of Venting Devices

3.1 *Open Vents*

Open vents may be used to provide venting capacity for tanks in which oil with a flash point of 100 F and above is stored.

3.2 *Breather Valves*

A breather valve or valves, may be used on any tank. Their use is suggested on tanks storing oil with a flash point below 100 F, except on tanks under 2500 gal capacity, and on tanks under 3000-bbl capacity storing crude oil.

3.3 *Emergency Vents*

3.31 For the purpose of accommodating abnormal vapor efflux, which might occur during exposure fire, tanks should have some device or form of construction which safely will relieve excessive internal pressure. This may take the form of additional or larger open vents or breather valves; a self-closing gage hatch or manhole cover, or a manhole cover with long bolts that will permit the cover to lift under internal pressure; or a seam in the roof or connection between the roof and shell which is weaker than the weakest vertical joint in the shell; or the shell-to-bottom connection.

3.32 Any cone-roof tank which has a diameter of 36 ft or over, and a roof attachment essentially similar to that of API Std 12A, 12B, 12C, or 12D, should be regarded as having a weak roof connection and, therefore, will not need to be provided with emergency vents. Other forms of construction which provide a demonstrably weak attachment are equally acceptable.

3.33 Emergency relief vents should be provided:
On each horizontal tank.
On each vertical tank having a domed or umbrella roof—unless built according to API Std 12C.
On each tank containing an oil the Reid vapor pressure of which is higher than 18 psi.

3.34 The capacity of emergency relief devices, except as stated in Par. 3.33, should equal the difference between the total relief capacity shown in Table 2 and the sum of capacity required for inflow of the oil into the tank (Par. 2.11 or 2.12) plus thermal breathing (Par. 2.13 or 2.14).

3.35 If a tank is equipped with a pressure-opening self-closing emergency relief vent, the emergency vent can be regarded as satisfying one-half of the required venting for inflow of oils with a flash point below 100 F, or one-half the required thermal pressure venting for any oil.

3.36 These emergency relief devices should provide the aforementioned capacity at a pressure which will avoid danger of shell or bottom failure.

4.0 Testing of Venting Devices

At least one production model of every type and size of venting device shall be flow tested under the conditions listed hereinafter.

4.01 Tests may be made by the manufacturer if certified by a qualified impartial observer, or may be delegated to an outside agency.

4.1 *Capacity Data*

4.11 Capacity data shall be presented in the form of curves or tables which give the volume of flow through both vacuum and pressure ports, and which cover the full range between the opening pressure (or vacuum) and the pressure (or vacuum) at which the ports are fully open.

4.12 Capacity shall be expressed in terms of cubic feet per hour of free air at 60 F and pressure of 14.7 psia.

4.13 Pressures shall be expressed in inches of water but auxiliary scales shall be expressed in ounces per square inch; other units may also be included, if desired.

4.14 Sufficient measurements should be made at pressures in the vicinity of the opening points, and particularly at 1.15, 1.25, and 1.50 times the opening pressure or vacuum, to clearly establish the flow capacity at those points.

4.15 The pressure or vacuum at which valve disc reaches its full open position shall be noted in the capacity-data sheet.

4.16 Capacity data shall include a statement of the manner in which the valves were tested. If any fluid other than air is used in the test, this fact shall be noted on the test report, together with the temperature of the fluid actually used and its specific gravity at standard conditions.

4.2 **Test Conditions**

4.21 *Mounting of Venting Device*

4.211 Valves shall be mounted for test on straight pipe nipples which have the same nominal diameter as the size valve and a length 1½ times the nomi-

TABLE 1
Thermal Venting Capacity
(Expressed in Cu ft per hour of air)

Tank Capacity* (Barrels) (1)	Inbreathing (Vacuum) All Stocks (2)	Outbreathing (Pressure) Flash Point 100 F and Above (3)	Outbreathing (Pressure) Flash Point Below 100 F (4)
1,000	1,000	600	1,000
2,000	2,000	1,200	2,000
3,000	3,000	1,800	3,000
4,000	4,000	2,400	4,000
5,000	5,000	3,000	5,000
10,000	10,000	6,000	10,000
15,000	15,000	9,000	15,000
20,000	20,000	12,000	20,000
25,000	24,000	15,000	24,000
30,000	28,000	17,000	28,000
35,000	31,000	19,000	31,000
40,000	34,000	21,000	34,000
45,000	37,000	23,000	37,000
50,000	40,000	24,000	40,000
60,000	44,000	27,000	44,000
70,000	48,000	29,000	48,000
80,000	52,000	31,000	52,000
90,000	56,000	34,000	56,000
100,000	60,000	36,000	60,000
120,000	68,000	41,000	68,000
140,000	75,000	45,000	75,000
160,000	82,000	50,000	82,000
180,000	90,000	54,000	90,000

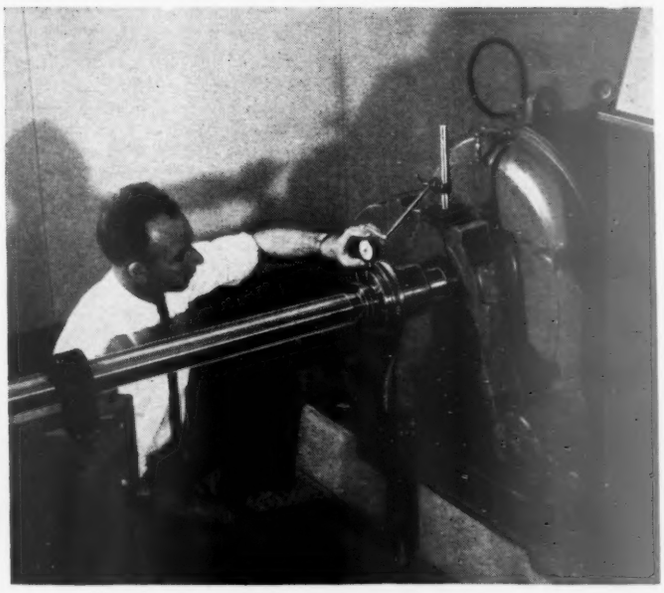
* Interpolate for intermediate sizes.

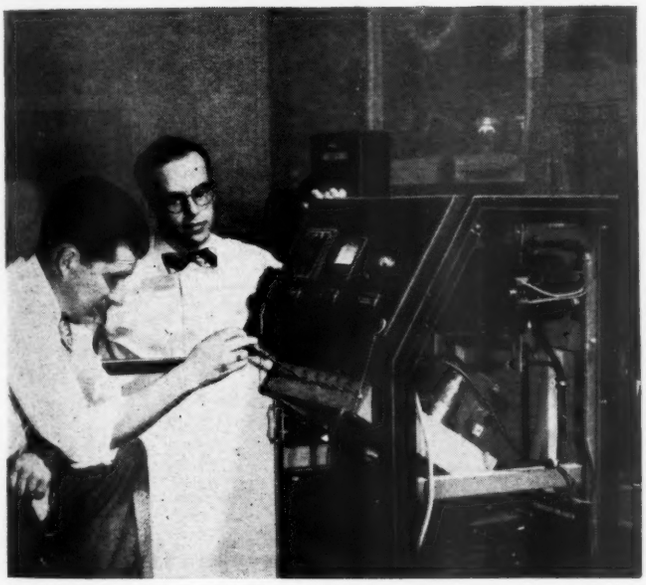
*This guide attempts to outline a safe and reasonable practice for the normal temperate-zone climate and normal operating conditions. The many variables which must be considered in connection with tank-vent problems make it impracticable to set forth definite simple rules which are applicable to all locations and all conditions of operation, as, for example, tanks in which oil is heated or which receive oil from wells or traps. Engineering studies of any particular tank may show that it is desirable to use either a larger or smaller vent capacity than that estimated in accordance with this guide.

TABLE 2
Total Pressure-Relief Capacity of Vents

Capacity of Tank* (Gallons)	(Barrels)	Total Outbreathing Pressure Vent Capacity (Cubic Feet of Free Air Per Hour)	Approximate Diameter (Inches) of Free Circular Opening Required for Various Tank Pressures: 3 In. of Water	1 PSI	2½ PSI	5 PSI
1,000	23.8	25,300	4	2	2½	1½
4,000	95.2	69,500	6¾	3¾	3	2½
18,000	428	139,000	9½	5½	4½	3¾
25,000	595	166,000	10¼	6	4¾	4
56,000	1,330	253,000	12¾	7¼	5¾	5
100,000	2,380	363,000	15¼	8¾	7	6
155,000	3,690	458,000	17¼	9¾	7¾	6½
222,000	5,290	522,000	18¼	10½	8¼	7
475,000	11,300	624,000	20	11¼	9	7¾
735,000	17,500	648,000	20	11¼	9¼	7¾
Unlimited		648,000	20	11½	9¾	7¾

* Interpolate for intermediate sizes.





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nal diameter, except that valves to be used on production tanks shall be mounted on the test equipment in the same manner as they are to be mounted in the field. In addition, manufacturers supplying special mounting nozzles may test their valves when mounted on these nozzles in the same manner as they are to be mounted in the field.

4.212 The valve shall be mounted with its axis in a position normally used on a tank.

4.213 To minimize the effect of entrance losses, the venting device shall be mounted on the top of the test tank at a location near the center of an area which is essentially flat, and which has a diameter at least five times greater than the nominal diameter of the device to be tested.

4.214 Straight pipe nipples shall squarely enter the top of the test tank near the center of the flat portion, with the end of the nipple flush with the inside of the chamber. No rounding of the entrance is permitted. When supplementary tests are run on valves mounted on special fittings, these fittings shall be placed near the center of the flat portion and secured in the same manner as normally secured on a tank.

4.22 *Test Tank*

4.221 The test tank shall be provided with suitable means, such as perforated plates or screens, to prevent high-velocity jets from impinging on the venting device.

4.222 Provisions shall be made to dampen pulsations in the air supply that may cause errors in flow metering.

4.23 *Flow Metering*

4.231 Air or other suitable gas shall be employed in testing.

4.232 Air or gas flow shall be measured preferably by an orifice meter that uses pressure tap locations and corresponding coefficients given in the 1935 report of the AGA-ASME Joint Committee on Orifice Coefficients, and as summarized in the ASME publication *Fluid Meters* [4th edn. (1937) Part I, Chap. C-4] and subsequent amendments. Flow measurements taken by other methods will be accepted — provided the equipment employed yields reproducible results, and provided it has been actually calibrated against measurements by the standard orifice meter over the operating range for which it is used.

4.233 Static pressure or vacuum shall be measured with a differential or inclined tube manometer, or other means capable of reading pressures which are correct to within 4 per cent of opening pressure.

4.234 Differential pressure shall be measured as prescribed in Par. 4.233.

4.235 Provision shall be made for changing orifices so that no flow measurements are made with a differential pressure across the orifice of less than 0.4 in. of water.

Corrections

4.241 Note that the formula in *Fluid Meters* (Par. 4.232) gives the volume of *standard air* (or gas) which flowed through the valve at test conditions. What is wanted is the capacity of the valve, in cubic feet per hour, of *standard air* at *standard* conditions. Hence a correction is required to get the rated capacity *which would have been obtained* if the test had been conducted at exactly 14.7 psia and 60 F.

4.242 A correction is also required if the test was actually performed on gas instead of air. The correction factor is the square root of the ratio of the density of air at standard conditions to the density of the test medium at test conditions.

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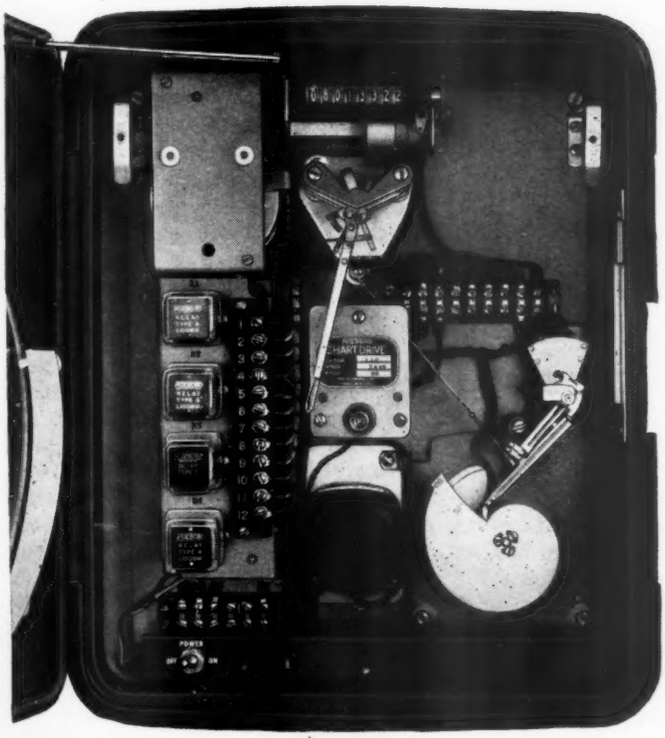

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As more and more emphasis is placed on preventing corrosion, professional people specializing in corrosion prevention are becoming concerned over malpractices being committed in various areas of their work. The author of this article, a corrosion engineer and registered professional engineer, cites certain problems, makes recommendations. Comments will be welcomed.

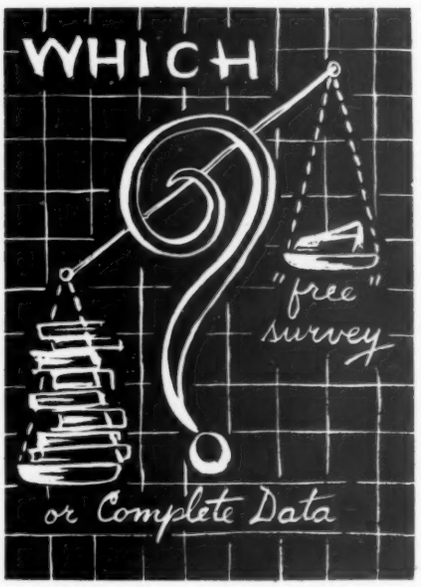
What's a Corrosion Survey Worth?

Marshall E. Parker

YOU, as the owner of certain facilities that include some metallic structures underground—such as piping—have become concerned about the corrosive attack of the soil on those structures, and what can be done about it. Perhaps you have already experienced leaks, or perhaps the experience of others in the same general neighborhood have aroused apprehension in your mind. You decide you would like to have a corrosion survey made. What can you expect to receive from such a survey, what will it be worth to you, and how much should you pay for it?

It is often possible to get a "free" corrosion survey; this you should value at just about what it costs. Actually, such a survey is not free; it will be paid for, either by you or by the others who buy the goods or services available. A free survey can be offered only by someone who hopes to sell you something later on; it will indicate only the extent to which you are a possible customer for the particular line being offered. In any event, all that you are likely to receive as a result of this type of survey is a quotation. Even if the field work, which is likely to be somewhat sketchy, discloses quite a bit of data, you are not going to receive it; all you will get is a recommendation to purchase and install such and such equipment.

If you are in a position to know just what you want, then all you are interested in is a quotation, and you certainly don't expect to have to pay for one. But if you don't have a corrosion engineer, or a staff member who is qualified to evaluate your problems and design measures against them; or if, having such men, they are too busy with other duties, or do not have the specialized instruments necessary — if, for any reason, you must depend upon outside help for engineering in the corrosion field, then what you need is a survey, not a quotation. And for a survey you must be ready to pay an amount commensurate with the time required, the specialized skills needed, and the equipment used.



If you are going to pay for a survey, then by all means you should get one, and not just a recommendation and a quotation.

Among other things, you should get *all* of the field data taken. It may be condensed or summarized, but it should all be included. Also if you really want it, and specifically ask for it, the engineer making the survey should be happy to supply you with exact copies of the field notes, or even with the originals. These will include all of his bad guesses and his mistakes; they will include all of the puzzling and inconsistent data, some of which he may not be able to understand or to explain fully. Whatever they are, you are entitled to them, in as much detail as you desire.

Also you should get an analysis of the data. In many cases, where the problem is relatively simple and there are not too many complicating factors, this analysis will be very brief; in others it may be very complex. Whichever is the case, you are entitled to it; it was made on your structure, on your problem, and you are paying to have it done; therefore it is yours, and you should receive it. This analysis should include, for your benefit, all of the calculations made, and an explanation of the process; thus you will be able to follow the reasoning involved, and to determine the basis on which the recommendations rest. At least the analysis will be in your hands, so that you can check it or have it checked. Often such an analysis will contain references to published literature as a substantiation for the methods used.

The completeness of this analysis, the degree to which you are permitted to see inside of the process, will provide for you a useful clue for evaluating the engineer or organization making the survey. *For there are no secret formulas in cathodic protection.* It is not a magic process, and the differences between engineers lie in their knowledge, experience, and the skill with which they apply certain well known principles (and in such basic elements as honesty and integrity), rather than in any trade secrets which some of them may claim to possess exclusively. View with profound suspicion any process or device, in this or any other

*Consultant, Houston, Texas.

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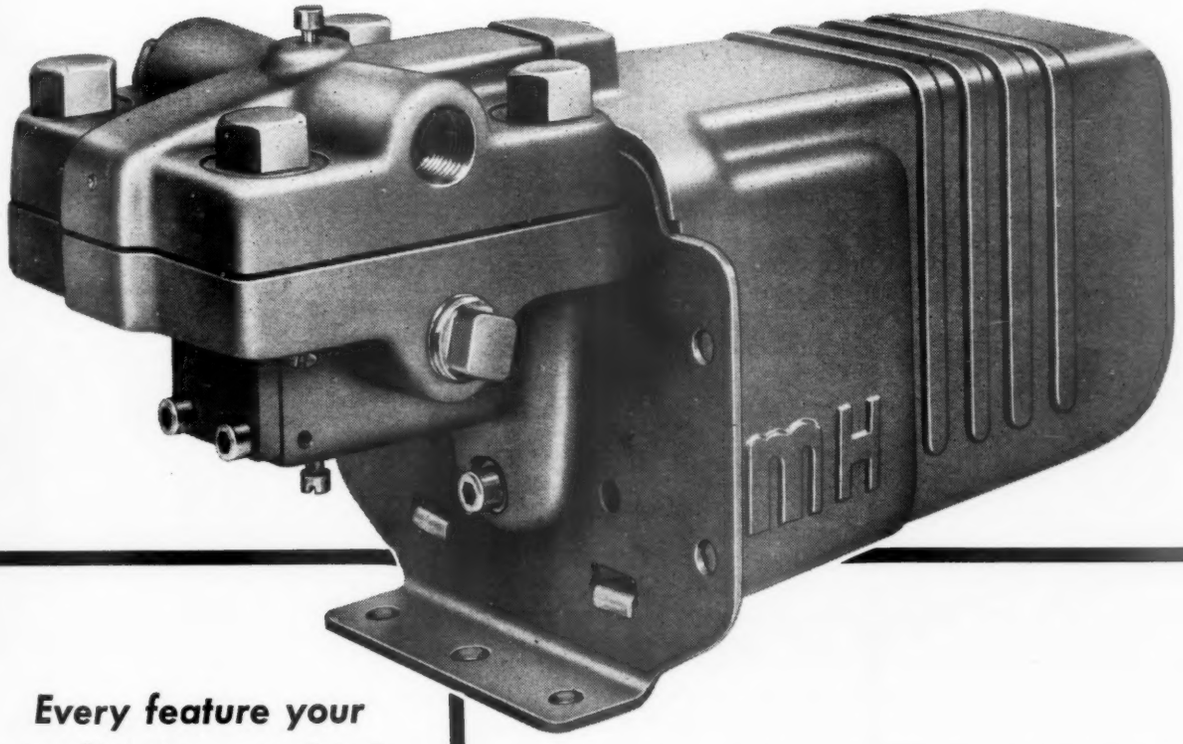

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technical field, which is described solely in terms of the results claimed for it, without a straightforward explanation of the method by which the results are achieved.

The analysis should be summed up in conclusions and recommendations. Often, in a well written report, these are given briefly at the beginning of the report. When you have full confidence in the engineer, you do not really need to read the supporting data; but it is a bit difficult to have that confidence when the supporting data are not there. The recommendations may be very simple, or there may be presented a number of alternate plans. If this is the case, they should be discussed and compared, so that you will be able to choose among them. The engineer is often not in a position to make this choice, as it may involve factors as the tax and earnings position of your company, planned life of the facilities involved, and other matters concerning which only your own management can be fully informed.

Normally, recommendations will set out the type of protective system to be installed, the number and rating of the units, and their general location. Unless the original agreement has so specified, there will not be included a complete detailed design for any one of the recommended systems.

In the first place, preparation of detailed plans for each recommended system would involve a needless expense, as only one of them will be used; and it is not necessary to design them completely in order to judge their relative merits. Also, in many cathodic protection installations, the system is not fully designed in advance, but is fitted to the protected structure by field modification. This results in an overall saving.

The report should include a quotation, or several quotations, perhaps for a complete turnkey installation, or for a set of plans and specifications upon which competitive bids may be obtained, together with an offer covering supervision and final inspection. Several combinations may be offered. The deciding factor here is likely to be the set of conditions found in the survey; some situations lend themselves to one treatment better than another.

Whatever the conclusions reached, the recommendations made, though, you are entitled to all of the data on which they are based, and to a substantial insight into the process by which they were reached, and you are entitled to all of the conclusions reached. For all of this, you must be prepared to pay a reasonable sum, just as you would for any engineering service. * * *

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The Time for Planning Is Now . . .

Wartime Security Measures for Pipe Lines

Some wartime security measures have useful peacetime applications; more rigid measures must at least be planned and ready for action

C. B. Lester and H. T. Chilton, Jr.

THE U. S. PIPE LINE INDUSTRY HAS been in existence almost 100 years. Yet, in all its history, it has never been bombed, never been the subject of invasion attack, nor suffered seriously from sabotage.

Today we live in a world where unrest has become routine, and where the threat of enemy action is seldom out of mind.

Therefore, it is only realistic that we should consider how our vital commercial pipe lines can be maintained at maximum capacity should they become the subject of enemy action, because these lines are the backbone feed for all the free world's military pipe lines.

Military pipe line designers have the problem of military security uppermost in their minds. With this as a prime consideration, cost becomes a secondary factor; i. e., a military pipe line can repay its entire cost in the first day of wartime operation.

In our free-enterprise economy designers cannot disregard cost. Additionally, we do not normally consider wartime defense measures in the design of our systems because: 1, They may not be needed; and, 2, they can be extremely costly.

Should an all-out war occur, the security of our commercial lines will become of major importance. Therefore, we would be wise if we would take some time to consider the problems of providing military security for our commercial line—both those now built and operating and those yet to be built.

The purpose of this article is not to sound false alarms but, rather, to suggest realistic thought and action that will insure better continuity of the transportation of military fuel during emergency periods.

Pipe Line Security Measures

We may define pipe line security measures as *"those extraordinary precautions taken to insure the continuity of operation of a pipe line, whether the measures be designed to prevent damage, or to assist in quick and efficient repair, once damage has been incurred."*

Our industry has always been noted for its ability to take care of emergencies arising from any kind of action. In a normal year lightning will strike our tanks; fires will break out in our pump stations; and we will have leaks or breaks in our high-pressure lines. Yet the lines are back in operation in a very short time.

The differences between these emergencies and those caused by an enemy will be a matter of degree. There will be more of them—and, directed by a thinking enemy, they can be expected to occur at our most important installations on our most important lines.

Basic Considerations

We can resolve the action of an enemy into three phases, each of which requires a different type of defense:

1. Sabotage
2. Air attack
3. Land invasion

We can also divide a pipe line system into three kinds of installations, each of which presents a different security problem:

1. Pipe lines
2. Pump stations
3. Tank farms

Let us consider some basic aspects of protecting a pipe line system.

Pipe Line Vulnerability

Pipe lines are buried, but they still can be located from the ground or from the air. They traverse long distances, and they are continuous; i.e., a break in any part will interrupt the continuity of the whole.

Pipe lines never can be fully protected against sabotage. One man with a shovel and a stick of dynamite can shut down a long stretch of line. Important points can be guarded, but you can never continuously guard an entire pipe line.

From the air, the lines are a difficult target because they are narrow and buried in the earth—and earth cover is the best natural defense against any type of explosive. Therefore, they should be relatively safe from bombing or from the action of distant guns during land invasion.

Once the enemy has overrun an area in which pipe lines are located, the problem will be effectively to destroy them so that they will not be of any advantage to the enemy.

Pump Station Vulnerability

A pump station, on the other hand, is a concentration of valuable equipment in a small area. We can defend it against sabotage because we can apply to it manpower of sufficient quantity and quality to give it every operating chance.

To protect a station from air attack, we can take protective measures, but none of these will offset heavy direct hits. For example, it can be:

1. Partly buried, sandbagged, or protected with concrete splinter walls.
2. Its piping and manifolds can be shielded or mounded with earth.
3. The entire area can be camouflaged.

All these measures make attack more difficult, but they cannot change the unalterable: If a pump station gets a direct hit, it's going to be put out of business—and probably for a long time. The problem then will be to replace rather than to repair.

Invasion presents a similar problem. Direct hits by long-range guns or tactical air forces will probably put the entire station out of commission. All we can do is to make the attack more difficult and less effective.

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Tank Farm Vulnerability

A tank farm is a large, easy-to-hit installation. It is not continuous, however, and the loss of one or two tanks should not shut down the system. Thus a terminal presents problems that are a kind of hybrid between those of the line itself and those of the pump station.

This thinking, of course, is tempered by the relative vulnerability of tanks. A thin-walled steel structure—a tank—can be put out of business by bomb splinters, or even by strafing or by small-arms fire. We may strengthen our defenses against sabotage, or partly bury or shield the tanks against near-miss bombs or strafing; but a direct hit on a tank will take it out of commission—probably permanently.

Military designers are consciously concerned with security measures to protect the vulnerable spots on a pipe line. Naturally the degree of protection varies with the location and the importance of the facilities. This should also be true of commercial systems; and any measures used on military pipe lines, in the event of an all-out war, could apply equally to our commercial pipe lines. What are some of these measures?

Pipe Line Security Measures

1. *Provide security guards* at all important points such as river crossings and vital junctions.
2. *Install security fencing* (even concrete or earthen walls) at junctions and block valves to make them less accessible and to ward off hand-thrown explosives and small-arms fire.
3. *Increase air and ground patrol* along the line.
4. *Set up a formal reporting system* with owners or residents along the line. These people are usually alerted to almost any unusual occurrences.
5. *Equip each line with monitoring instruments* to detect any abnormal operating conditions.
6. *Shield structures* above the ground with concrete walls or earthwork embankments.
7. *Remove visible evidence,* wherever possible, of the route of the line, and camouflage vital spots.

Pump Station Security Measures

1. *Enclose the property* with security fencing. In vital areas, light this fence and provide guards or guard dogs.
2. *Shield manifolds and equipment* with concrete walls or sandbags.
3. *Install bypass connections* and header gates far enough from the station to isolate it completely in case of fire or other emergency.
4. *Install fire-fighting equipment,* either fixed or heavy-duty portable types.
5. *Surround all manifolds* and building fronts with concrete walls or earthwork embankments. Enclose all buildings not of heavy masonry.
6. *Partly bury* the station and manifolds.
7. *Camouflage* the station.
8. *Supply all power needs* within the station, utilizing fuel from the pipe line.

Tank Farm Security Measures

1. *Surround the property with security fencing,* keeping well away from all tanks and appurtenances. Light and guard this perimeter.
2. *Shield manifolds and equipment* with concrete walls or sandbags.
3. *Collar the tanks* with concrete walls.
4. *Cover all piping* above the ground with an earth fill.
5. *Partly bury the tanks* and provide an earth cover.
6. *Space the tanks* so that one exploding tank will not set other tanks on fire.
7. *Protect transfer pump houses and appurtenances* the same as line pump stations.

Other Security Considerations

In times of emergency both administrative and dispatching functions take on added importance. We should avoid overcentralization of administration and massive communications "hubs" which, if lost, would drop major sections of a system. Our local loops should be planned so that they can be immediately replaced if they are lost.

Our wire lines are practically indefensible against sabotage, whereas very high-frequency and microwave systems can be guarded or splinter-proofed. VHF systems should be planned so that they can replace lost sections of the primary communications system, and they should be used point-to-point. A well-designed microwave system, backed up by a good VHF system, should be difficult to knock out completely—except by concerted sabotage action or direct hits.

In addition, we should be prepared:

1. To pump backward if need be;
2. To demolish our own lines completely as a last resort if we were overrun.
3. To destroy the fuel in the tanks and line.

This would mean a complete job—i. e., not merely breaking the line in a few places and blowing up the stations and farms, but taking such measures as pumping slugs of concrete or heavy mud into the lines at irregular intervals, loading the lines with contaminants to prevent later use, and taking out major river crossings.

Military defense construction for an uncertain war requires the expenditure of tremendous sums of money over and above that required for normal peacetime operation. Security measures can double or triple the cost of a pump station. A diversified, splinter-proof tank farm—with all concrete-collared or buried tanks, and with splinter-proof buildings and manifolds — may cost three of four times as much as a conventional tank farm. Thus expenditures for wartime security pose a good many problems in economics—whether we are spending the taxpayer's or a private company's money.

Emergency Maintenance

Obviously, we can never make a pipe line system secure to the extent, let us say, that we can make a command headquarters secure. We cannot hide it; we cannot fully shield the line from sabotage; we cannot protect the station facilities or tanks from direct hits; and, furthermore, serious damage to our facilities will probably result in a hazardous spill, fire, or explosion.

The Authors

C. B. Lester

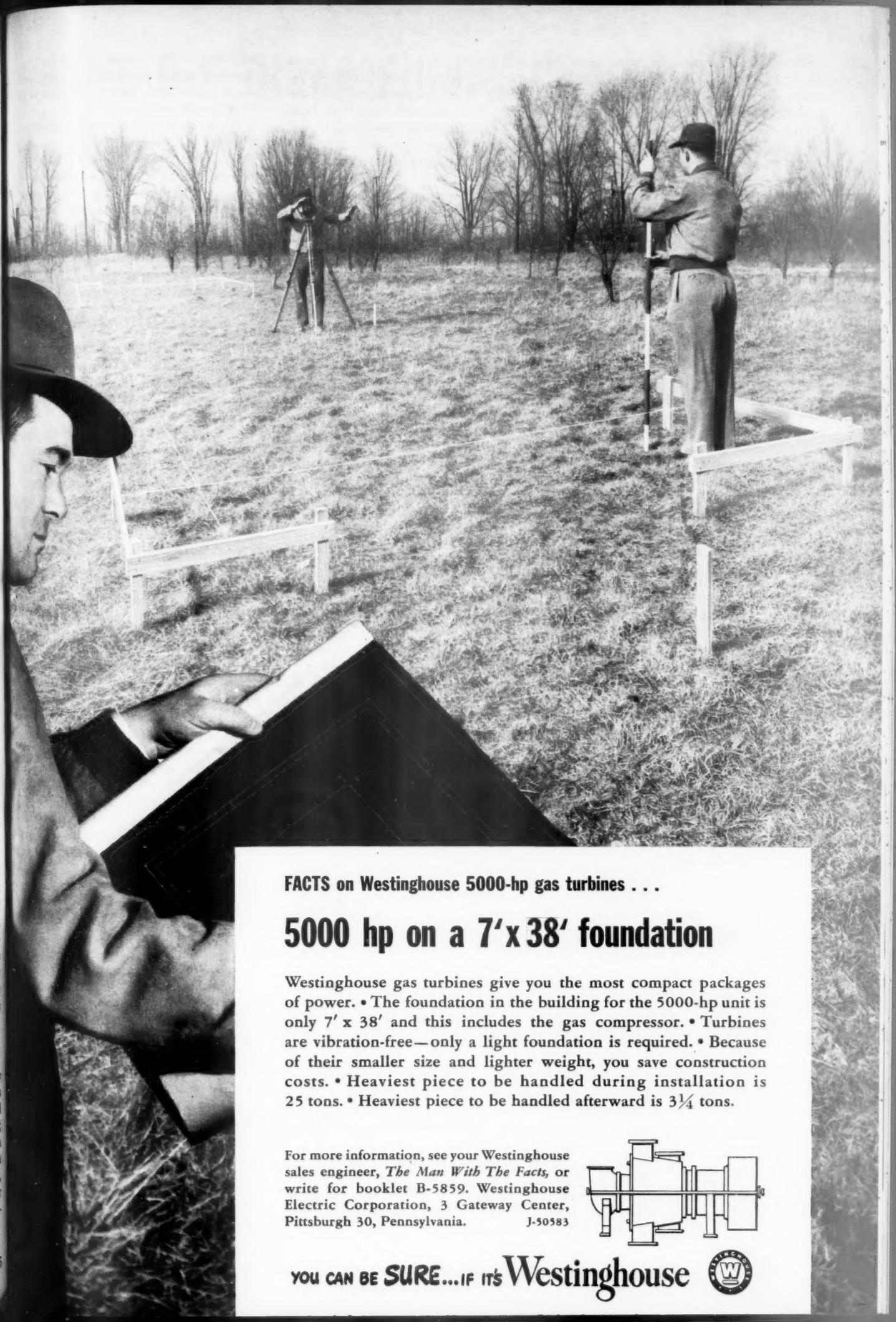
H. T. Chilton, Jr.

C. B. Lester has been chief engineer for Mid-Valley Pipeline Company, Longview, Texas, since 1950. He was awarded the API Certificate of Appreciation for services on committees of the API division of transportation in 1954.

Lester, who studied electrical engineering and physics at Purdue University and the University of Chicago, was previously employed by Standard Oil of Ohio and was head of Sohio Pipeline Company's research and development department.

H. T. Chilton, Jr., is maintenance superintendent for Service Pipe Line Company, Tulsa, Oklahoma. He joined Service in 1947 and served as oil traffic engineer and division chief engineer in the West Texas division until 1952 when he was made senior engineer in the Tulsa office. He served as executive assistant to the vice president of operations before assuming his present job.

He was graduated by The University of Texas with a BS degree in mechanical engineering and a BA degree in business administration.



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Therefore, we must prepare ourselves to be sabotaged, bombed, or otherwise temporarily put out of commission—then to restore service as fast as possible.

In this type of emergency maintenance, pipeliners have no peer. But if we are to handle many breaks on a continuing basis, we must plan our steps well in advance.

Above all, we must have skilled and resourceful maintenance crews strategically located. We must have on hand the best available transportation, work equipment, communications, and methods. We must have adequate and easily installed repair materials and equipment readily accessible.

Stockpiling emergency repair materials and equipment for one company, with any degree of completeness, can represent a very sizable expense. However, because the emergency maintenance problems that face one company usually face another, it appears that the most economical solution would be for pipe line companies operating in the same area to contribute jointly toward emergency stockpiles to meet their common needs.

Stockpiles of engine-driven temporary pumping units are a *must*. We can lose a pump station if it gets knocked out, or if the power system feeding it can no longer deliver. In fact, loss of a power system can put a pipe line out of operation without its ever being touched. Wartime operation of both the Big Inch and the Little Big Inch lines was eminently successful, but what if the power plants (which are prime targets) feeding them had been cut off?

Anyone who has ever pondered over having to provide emergency pumping equipment for a 5000-hp pump station can immediately see the magnitude of this problem. Ten 500-hp portable units, with their prefabricated manifold set, would take care of one station. But suppose four stations served by one power system lost their entire feed? We can handle these problems no matter how jury-rigged the replacements are, but planning and timing are extremely important.

A group of companies could stockpile spare river crossings of heavy-wall grade "A" pipe which could be welded and pulled across without weighting or coating. These would in no way be permanent crossings, but they would put a line back in service immediately. An isolated system not already so equipped might well consider going ahead and constructing a duplicate crossing.

Stockpiling of large tanks should not be a major consideration. We can temporarily replace them with smaller 5000-bbl or 10,000-bbl bolted tanks at a much lower stockpiling cost, and much faster than replacing them with large welded tanks.

Duplication of facilities is a problem without an answer. A 20-in. gasoline line can be forced to 300,000,000 bbl per day under wartime conditions; a 30-in. line in the news a year ago could handle about 3 times this amount. Yet, recognizing the tremendous capacities of these big products lines, we wonder what a determined group of saboteurs could do to them! Obviously duplication would not save them; it would merely double the enemy's task.

Conclusion

By now it should be evident that military security for commercial pipe lines poses problems with many pros and cons. Even if war occurs, we do not expect to be invaded or subjected to the enemy's tactical air forces. But we must expect the action of strategic bombers and, although we hate to admit it, organized sabotage. If we cannot completely stop the enemy, we can certainly make his work more difficult by taking certain preventive measures, and we can make his work less fruitful by providing the ability to make quick repairs and replacements.

Some security measures which could be considered mandatory in wartime also have definite peacetime advantages. Some of these are: Installing piping for the isolation and bypassing of damaged pump stations; installing VHF communications that could be used point-to point to replace primary communication circuits; stockpiling or providing spare river crossings; stockpiling portable pumping equipment; providing looped systems in critical spots; and planning emergency interconnections with other carriers. If such measures are considered in the light of wartime operations, perhaps we will find that we can afford more of them.

Above all, we must be able to repair or replace, and do it quickly. This must include stockpiling of essential gear. The economics of stockpiling favor joint participation between companies operating in the same area. To formulate and partly carry out a joint stockpiling plan during peacetime has many advantages over stockpiling by individual companies. To make such a plan operational in wartime would certainly be a worthwhile contribution to our national security because our ability to restore operations quickly, whatever the cause of interruption, is our most valuable and practical security measure.

Acknowledgment

This discussion was presented at the 6th annual API Products Pipe Line Conference in Chicago, Illinois, May, 1955.

* * *

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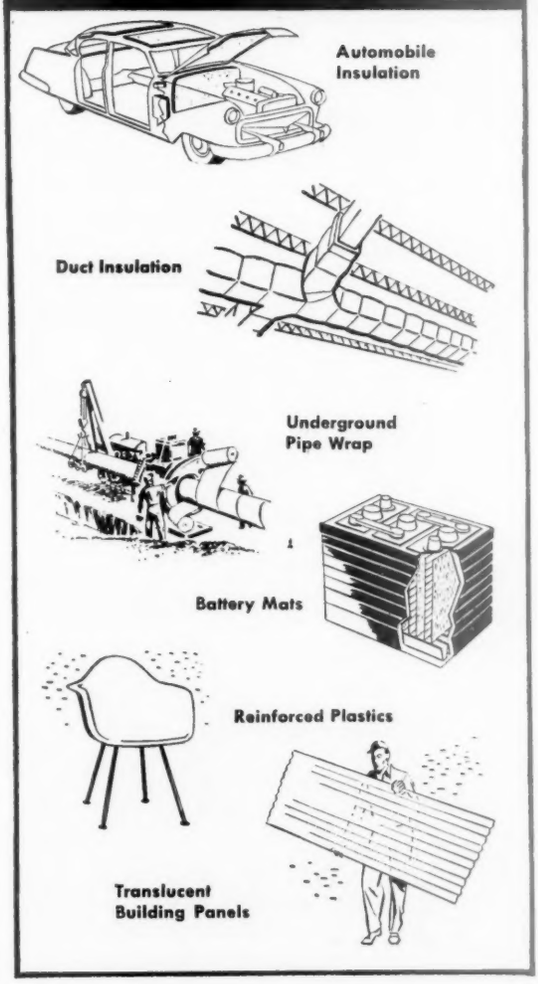

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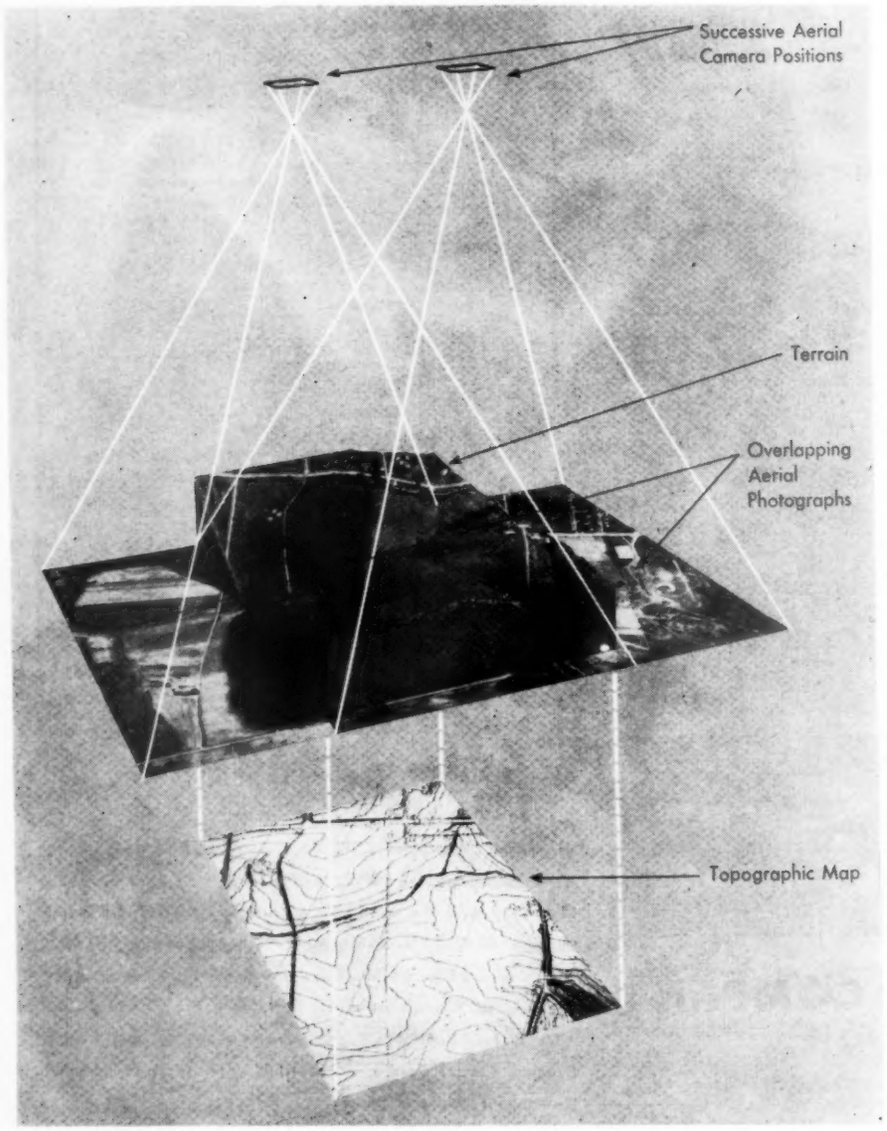
Here's how projectors replace comera positions back in the office. Through stereoscopic means, a small scale reproduction of what the camera recorded is recaptured.



WITH A ROUTE HAVING BEEN SELECTED by a stereoscopic study of the aerial photographs, photogrammetric mapping of the route may begin. The object now is to reconstruct in the office what the camera saw in the air in order to make measurements and make maps.

Actually, the taking of measurements and the plotting of maps are one operation. The transposition of the measurements from the photographs to a piece of tracing cloth is done by means of a graphic rather than a mathematical solution. This graphic solution is accomplished through stereoplotting instruments. These instruments come in various makes, models, and descriptions, each having its own advantages and disadvantages and each designed to best accommodate a general type or scale of mapping. The principles involved are the same in each.

Briefly, the principle of the photogrammetric process is a reversal of the aerial photography process. Two projectors are used and they are closely matched replicas of the aerial camera. These two are oriented so as to be in the same relative positions as the aerial camera occupied at two successive exposure points along the flight.

When oriented with the respective photographs in them they project these into space in a reversal of the photography process. The two overlapping projections intersect in space to form a true-to-scale, three dimensional, optical model of the terrain covered. A measuring system introduced into this model permits three dimensional measurements to any feature on the ground and provides semi-automatic means of plotting the results onto paper. The measuring system employs stereoscopic viewing by an operator and the view is similar to the view experienced with 3-D movies or amateur stereo slides.

One common photogrammetric instrument is the Kelsh plotter. This instrument is supported on a table slight-

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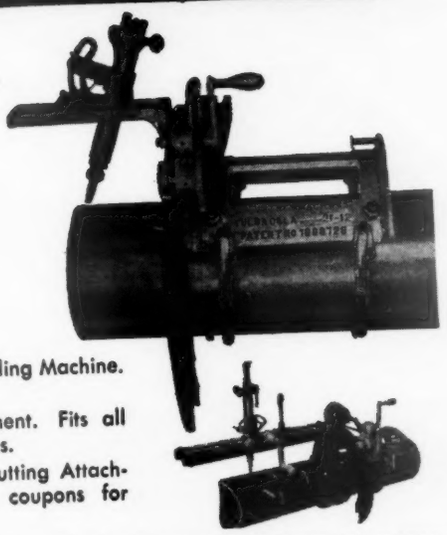

Illustrated above: Mathey Pipe Cutting and Beveling Machine. Cuts pipe at any predetermined angle.

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ly larger than an office desk. The table surface provides a reference plane for measurements as well as a drafting surface for plotting the results. A framework some three feet in height rests on the table at its four corners and provides a rigid support over the table for the two projectors.

Working in semi-darkness, they project vertically downward toward the table surface, giving two overlapping aerial photographs. These two projections intersect in space to create the optical model of the terrain some six inches above the table surface. The projections are actually viewed on the white surface of a small circular screen about four inches in diameter, carried on a small movable stand slid by hand around the table surface.

To separate the two projections for stereoscopic viewing by the operator, one is projected in red light and one in blue-green. The operator wears spectacles, one lens of which is red and the other blue-green. The result is that one eye sees the images from one projector and the other eye sees images from the second, the two fusing in his mind to create the stereoscopic view.

At the same time, in this stereo view, the operator sees a tiny measuring mark on the surface of the white screen. This he can place on the three dimensional position of any selected image. A vertical calibrated scale on the movable stand permits him to measure the height to a selected image. A pencil lead vertically beneath the measuring mark enables him to plot its position directly on the map sheet spread on the table surface below.

The instrument operator has spread out before him a terrain model, usually covering several square miles. He can instantly reach any part for study and measurement by sliding the movable viewing screen to the desired point. By sliding the stand, he traces with his measuring mark any desired features, such as river banks, roads, wood lines or fence lines, and the pencil point beneath accurately plots their map positions.

By adjusting the screen height until overlapping images are matched, the operator measures relative elevations of the terrain. Keeping the screen at a constant height, he slides it along the line where overlapping images are constantly matched, thus tracing a contour that is plotted into its map position by pencil below. Thus the operator has at his command not only the means of detailed study of all the characteristics of his terrain and topography, but also the means of portraying information in map form readily.

This method produces complete and accurate maps in a fraction of the time it would take to compile them from conventional field survey methods.

The foregoing is the essence of making accurate maps from aerial photographs, but it should be noted that photogrammetric mapping cannot be performed without some known distances and elevations within the area photographed. Such horizontal and vertical control can be obtained from many sources depending upon the mapping accuracy required. Existing quadrangle sheets, railroad plans, pipe line profiles, and the like can often save the necessity of sending a field party into the area to measure distances between objects visible in the photographs or to establish their elevations.

It is more usually the rule that field parties must establish some known distances and elevations within the photography in order that the model may be properly oriented in the stereoplotting instrument and the scale of the plotted sheet be established. Some of the more complicated instruments are designed to "carry" such control information forward from one model to the next, thus reducing the amount of control that needs to be established in the field.

By means of such mapping devices, strip maps of the selected route may be readily compiled. Strip maps are normally of a convenient size to cover 5 or

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6 miles of the route on each sheet at a scale of 1000 ft = 1 in. and allowing mapping detail to extend a mile or so on either side of the proposed center line of right-of-way. The map depicts all features that can be seen from the air such as the road network, railroads, streams, fences, crop lines, swamp, telegraph lines, forests, houses, etc. The selected route is of course also plotted on the map as "proposed pipe line location."

Where enough vertical control exists or its establishment is warranted, an accurate profile of the route can also be extracted from the stereoplotting instrument and plotted on the bottom of the strip map sheet.

In certain rugged terrain, where there are practically no man-made features, it is nearly impossible for a man using a map in the field to orient himself unless the map portrays the topographic relief by means of contour lines. On other pipe line projects, contouring would be a waste of time as it is in no way pertinent to either field stake-out or ultimate construction.

As a complete set of such strip maps covering the entire route can be obtained prior to any field survey, the entire planning and management staff of a pipe line project can have the advantage of knowing in advance of survey virtually everything they would know after the survey. Although no dimensions or angles are noted on the original strip maps, they are accurate enough to allow the scaling of distances and protracting angles.

Supplied with a set of photogrammetric strip maps, the right-of-way department is in possession of enough detailed information of the proposed line location that it can proceed to procure easements and materially reduce the usual swath of options and abstracts.

Although political boundaries such as property lines cannot be seen in aerial photographs, it is surprising how much apparent evidence of property boundaries can be seen. The approximate boundaries of property lines may be seen from the air in large portions of the country. The physical evidence appears in fence lines, crop lines, wood lines, roads, and railways. With all these features portrayed on the strip maps, it is not too difficult—by referring to county records and township plats—to determine and plot on the maps the outlines of each property owner's tracts. In sectionalized country, even where no physical evidence exists, the sections may be divided mathematically and the boundaries plotted within the degree of accuracy normally required for a pipe line easement.

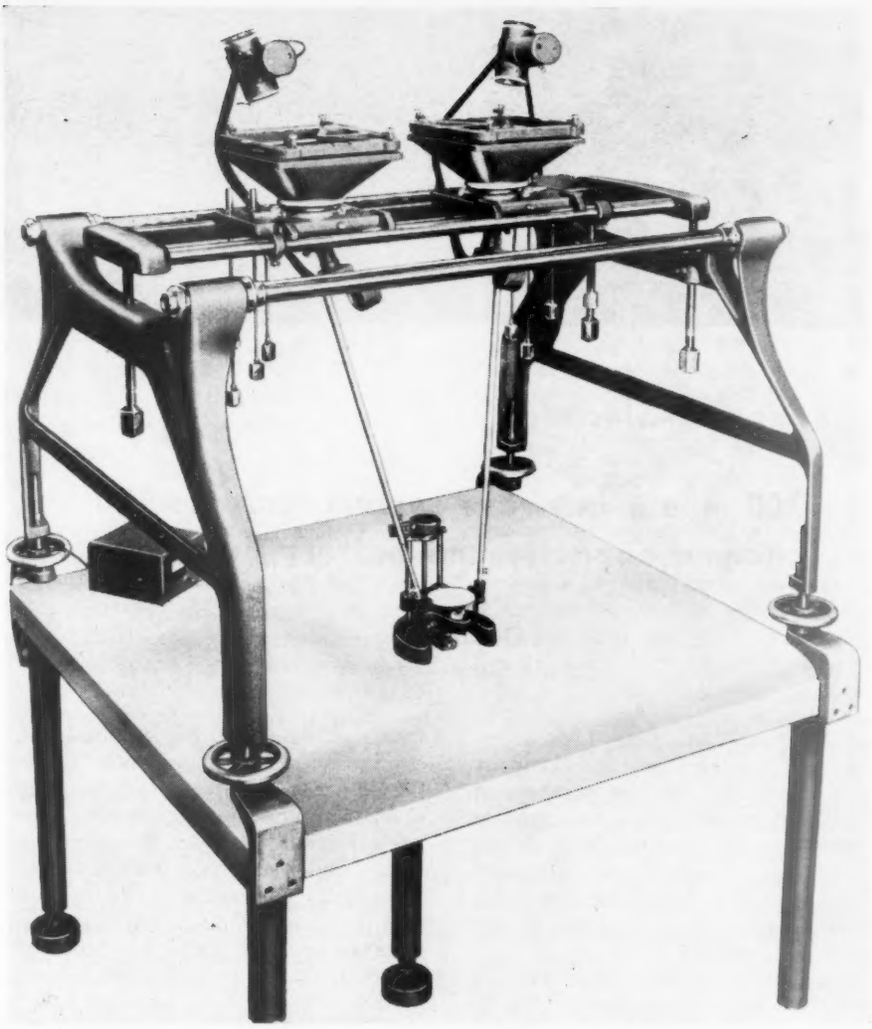
The same strip maps are also provided to field survey parties, primarily as instruction sheets telling them where to stake the line. If an unforeseen obstacle is encountered in the field and a slight deviation from the proposed line seems warranted, the field engineer need only notify the right-of-way department if the change involves a new tract of land.

Percentage-wise, such changes are negligible. The field party, however, keeps standard field notes regarding the centerline it stakes and when those notes are returned to the office the strip maps are changed from *"Proposed Location"* to *"As Staked."*

This transition involves a minimum of office drafting time. All that need be done is to erase the proposed route pencilled on the back of the linen and plot in ink the staked route, the deflection angles as pi's (points of intersections), and the stationing as measured in the field. If all goes according to plan, the new line coincides closely with the original proposed line, and the only change in the appearance of the map is the addition of actual field measurements.

It should be noted that these same aerial mapping techniques and stereo methods of route selection can be successfully applied to the location of microwave towers attendant to the communications systems so necessary to pipe line maintenance and operation.

It will be a major step in the coordination of pipe line construction projects when the communication facilities required for the final operation for the line are planned and established far enough in advance to be usefully adapted to the construction period. This is the time when an adequate communications system is so badly needed. The surveys needed for the establishment of a microwave system can very readily be integrated with the photogrammetric methods just described in connection with the actual route survey. * * *



This stereoplatting instrument is called a Kelsh Plotter. It reverses the aerial photography process and projects a true to scale, three-dimensional terrain model from which measurements are taken and maps plotted.

XUM

Continental-Sinclair

700 mile microwave system features 120 channel capacity and battery operation

Dean Hale
Oil and Gas Pipelining Editor

CONTINENTAL Pipe Line Company and Sinclair Pipe Line Company have announced the joint purchase of the largest privately owned microwave communication system. The shared system has a capacity of 120 voice channels and is termed the first "high density" microwave system in the petroleum industry.

The jointly owned system will extend 708 miles from Ponca City to Shawnee, Oklahoma, to Houston, Texas. Intermediate cities linked by the network include Oklahoma City, Wichita Falls, and Fort Worth.

A total of 27 stations, spaced approximately 30 miles apart, will be employed in the radio relay system. The microwave stations will operate in the 6700 mc band of frequency allocations, subject to approval of the Federal Communications Commission.

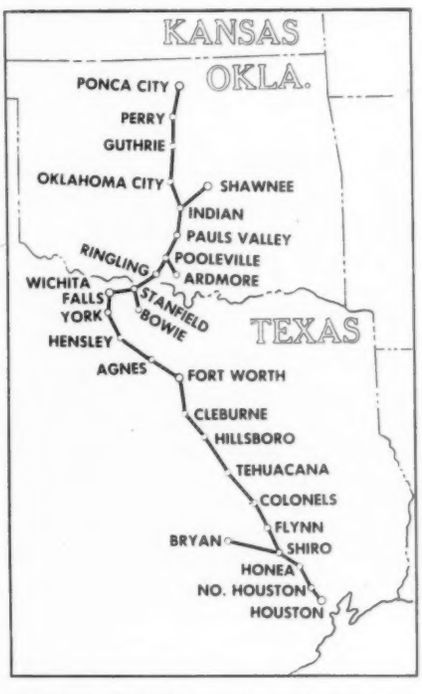
The Continental-Sinclair microwave system is unique in the petroleum industry in the use of float-charged storage batteries instead of standby engine generators. The battery-operated system is designed to avoid any loss of communication during power line outage. The battery system will supply continuous, uninterrupted power without delays due to engine starting or generator control malfunction.

The microwave system will be engineered, manufactured, and installed for the two pipe lines by Collins Radio Company. Microwave and multiplex equipment for the network will be manufactured in Collins' Dallas, Texas, plants.

System Plans

The entire microwave system was planned to rigid specifications of the two pipe lines. Strong emphasis on continuity of communication is reflected in the specification of not more than 25 millisecond outage time during any failure of power line or equipment. Fully automatic switchover to standby RF equipment is employed at all trunk line and major terminal stations. In addition, standby is provided for multiplex equipment, which is common to all channels. This multiplex standby provides automatic switchover of individual units in event of key unit failures.

An automatic fault finder will be used to detect and flash alarms to four maintenance stations in the event of trouble at any of the 27 stations.



Continental-Sinclair radio relay system.

Parabolic antennas, 6-ft in diameter, will be used throughout the system to provide maximum built-in fade margins. A fade of 33 db over the longest path will not affect communications over the system.

At downtown building-top sites such as the Petroleum Building in Houston, and the Fair Building in Fort Worth, the dishes will be beamed directly at the next stations. At sites requiring towers, the dishes will be aimed upward toward 8-ft by 12-ft passive reflectors, which are mounted on top of the towers. These reflectors bounce the narrow microwave beams, mirror-like, on to the next stations.

Towers in the system will be constructed for a maximum twist of $\pm$ 0.5 degrees for high rigidity under severe wind conditions and to assure long tower life. Tower heights vary from 140 to 360 ft, the highest being at Oklahoma City.

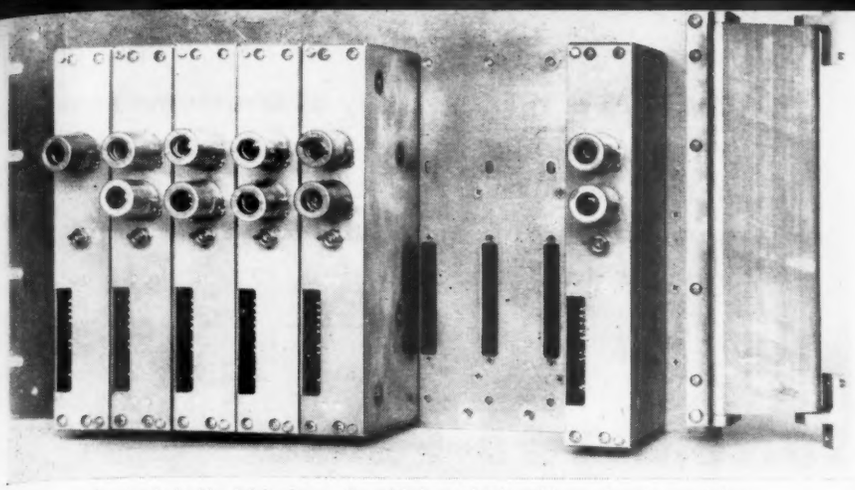
Buildings will be poured concrete employing monolithic construction. The separate compartment that is normally used as an engine generator room will be used to house the batteries and charges in this battery operated system.

The overall system is designed to provide voice channel signal-to-noise ratios of 60 db. Path lengths average 27 miles between stations. The shortest path is 14 miles northward from Houston. The longest path is 39 miles.

High Channel Capacity

The channel capacity of 120 voice channels will provide an overall system capacity of 85,000 channel miles. This figure exceeds the number of voice channel miles of microwave communication now in use in the entire petroleum industry, according to the survey reported in the April issue of *The Petroleum Engineer*.

Channels will reportedly be employed for VHF base station operation, teletype, telemetering, supervisory control, facsimile and voice circuits.



Typical shelf of 20-channel multiplex which utilizes plug-in modules, printed wiring boards and mechanical filters.

The high channel capacity is obtained by multiplexing many single sideband channels onto a broadband microwave carrier. The techniques of single sideband multiplexing and group modulation are basically the same as employed in the transcontinental radio relay network.

The multiplex equipment is a high density version of the Collins mechanically filtered mutiplex system. The 120-channel system is unique in its use of etched wiring boards instead of hand-wired circuits.

The accompanying photograph of a typical multiplex shelf illustrates the modular construction employed in the design of the 120-channel system. This shelf holds up to 8 miniaturized plug-in modules to provide four duplex channels in 10½ in. of rack mounting space. The multiplex units shown in the photograph were on display at the PIEA show in Houston and attracted considerable interest among pipe line communication men.

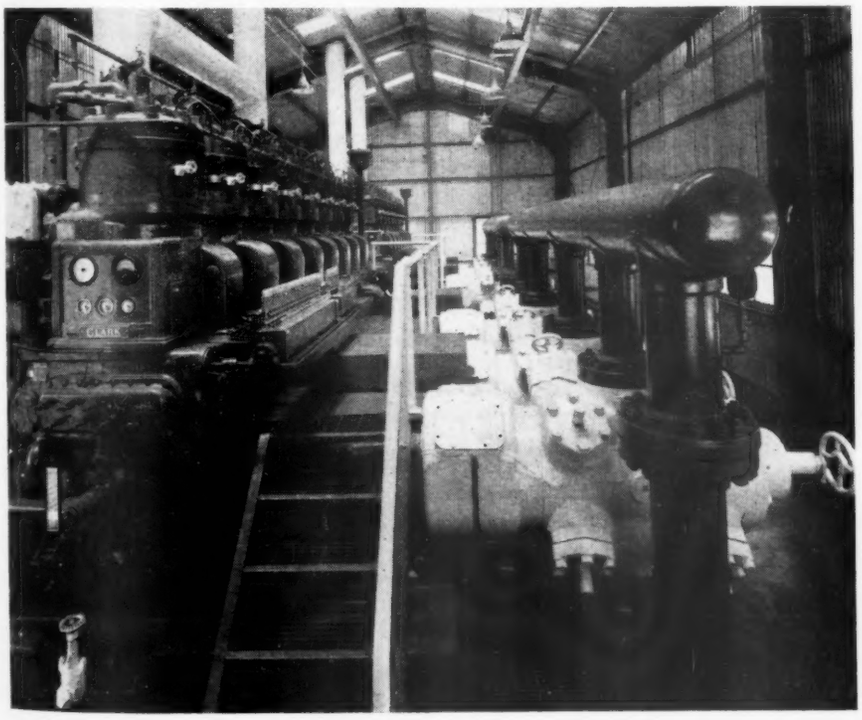
Battery Operation

The Continental-Sinclair system marks the first time a pipe line microwave system has been designed for a-c operation from battery power supplies. The use of float-charged batteries instead of standby power generators was suggested by Continental and Sinclair to bidders as a reliable means of providing continuous operation of remote microwave stations.

Battery chargers connected to the primary d-c power line will be used continuously to float charge station battery banks. A 60-cell bank will be floated in parallel with the 130-volt charger and the d-c plate circuits of the equipment. A rotary inverter will operate off the 130-volt battery tank to provide 115 volts a-c as required for special circuits during power line outages. A 12-cell bank will be floated in parallel with the 24-volt charger and the d-c filament circuits. Each bank of storage batteries will have a reserve capacity adequate to power the station for 12 hours of operation in the event of power line outage. In case of a sustained power line outage, several mobile engine generators will be available to operate the stations until service can be restored.

At several major city locations such as Houston, the primary power source was judged sufficiently reliable to dispense with standby power. Three spur terminals also have no standby power source. At such a-c operated stations there are no batteries provided. The a-c stations will use a new type of power supply unit that uses magnetic amplifiers for regulations of the 130-volt rectified output. * * *

Compressor Station at Orange, Texas



Forty million cu ft of natural gas are flowing into the Transcontinental Gas Pipe Line system from this new 1600-hp compressor station of Texas Gas Pipe Line Corporation, near Orange, Texas. The 40,000,000 cu ft daily represents the largest single-package purchase of gas made by Transco since the 1800-mile system went into operation in 1951.

Loops On California Gas Line Planned

Southern Counties Gas Company, Los Angeles, California, has asked permission from the California Public Utilities Commission to construct 31.5 miles of 30-in. pipe line on the California portion of its pipe line between Cactus City and Desert Center in Riverside County. The request would allow completion of the looping on the 210-mile line at an estimated cost of $2,533,555. If it is approved the company expects to begin work in the project in September, with completion scheduled for the middle of November.

New Socony Mobil Pipe Line Terminal Underway

Construction has begun on the new Socony Mobil Oil Company pipe line terminal at Tremley Point, near Linden, New Jersey. The new terminal will replace facilities that the company leases in Perth Amboy.

The terminal, expected to be completed about October 1, will be supplied from Socony Mobil's ocean terminal on Staten Island by a new pipe line to be laid across Arthur Kill. It will be one of the few terminals supplied by a pipeline from a terminal in another state.

XUM

Research at the University of Oklahoma provides calculation methods for solving two-phase pressure drops; aids in making economic studies of single lines to handle simultaneous gas-liquid flow

Horizontal Co-Current Two-Phase Flow of Fluids in Pipe Lines

Philip D. White*

R. L. Huntington**

THE characteristics of the flow of two phases with a common interface is an extremely important and very complicated subject. While many investigators have studied some of the aspects of the overall problem in the last century, little concrete information is available. Gas-liquid transfer is probably the most common type of two-phase flow encountered in industry, yet due to the complex nature of this type of flow a satisfactory means of calculating the pressure drop is not available.

To an increasing degree, the problem of simultaneous transfer of a gas and liquid is being encountered in industrial processes today. In pipe line gathering systems, the problem is frequently encountered, as the trend today is toward central separators, treating, and processing plants. There is also the problem of the feasibility of injecting a liquid drying agent into natural gas lines to reduce hydrate formation. In order to conduct an economic study of the advantages and disadvantages of single line gathering systems with central treating plants as compared to dual line systems and isolated treating plants, the engineer needs a means of calculating two-phase pressure drops.

In many operations, the use of two-phase flow is a matter of necessity, not one of choice. A few examples are: Chemical reactors; heat exchangers; horizontal tube evaporators, and reboiler return lines. In the design of these units the two-phase pressure drop may be of vital importance, and the need of additional experimental data is great.

*Magnolia Petroleum Company, Research Laboratories, Dallas, Texas.
**School of Chemical Engineering, University of Oklahoma, Norman, Oklahoma.

EXCLUSIVE

Previous Investigations

The pressure drop resulting from horizontal two-phase flow is in all cases greater than the pressure drop for single-phase flow of either phase alone. The belief that a small amount of liquid in a condensate gathering system would result in a lower pressure drop in the gas phase is false. Engineers holding this belief were under the impression that the liquid in the line would have an effect similar to painting the inside surface of a pipe, giving a smoother surface and less pressure drop.

The introduction of a second phase in the same pipe causes a reduction in the available flow area to both phases. As the pressure drop in a fluid flowing through a circular pipe is inversely proportional to the fifth power of the pipe diameter, the increased pressure drop resulting from this reduction in diameter is great.

The energy lost by the gas in accelerating and transporting the liquid is also

Terminology

X = Martinelli's flow parameter, dimensionless.

ϕ_g = Martinelli's flow parameter, based on pressure drop in gas phase, dimensionless.

ϕ_l = Martinelli's flow parameter, based on pressure drop in liquid phase, dimensionless.

f'_g = Schneider's pseudo friction factor, based on gas flow, dimensionless.

e = Energy Factor, $= \dfrac{2g_c D^6 \Delta P \rho_l}{L \dfrac{W_l^{3.6}}{W_l + W_g}}$ in units listed below.

R = Flow Modulus, $= \left(\dfrac{W_l}{W_g}\right)^{1.8} \times \left(\dfrac{\rho_g}{\rho_l}\right)^{0.9} \times \dfrac{1}{\mu_g^{0.1}} \times \dfrac{1}{\mu_g^{0.1}}$ in units listed below.

g_c = Conversion factor in Newton's law of motion, ft/hr²

D = Diameter, feet

ΔP = Two-phase pressure drop, lb/ft²

W_l = Weight of liquid flowing, lb/hr

W_g = Weight of gas flowing, lb/hr

L = Length, feet

μ_g = Viscosity of gas, lb/ft hr

μ_l = Viscosity of liquid, lb/ ft hr

ρ_g = Density of gas, lb/ft³

ρ_l = Density of gas, lb/ft³

G_l = Superficial velocity of liquid based on full pipe diameter, lb/hr/sq ft

G_g = Superficial velocity of gas based on full pipe diameter lb/hr/sq ft

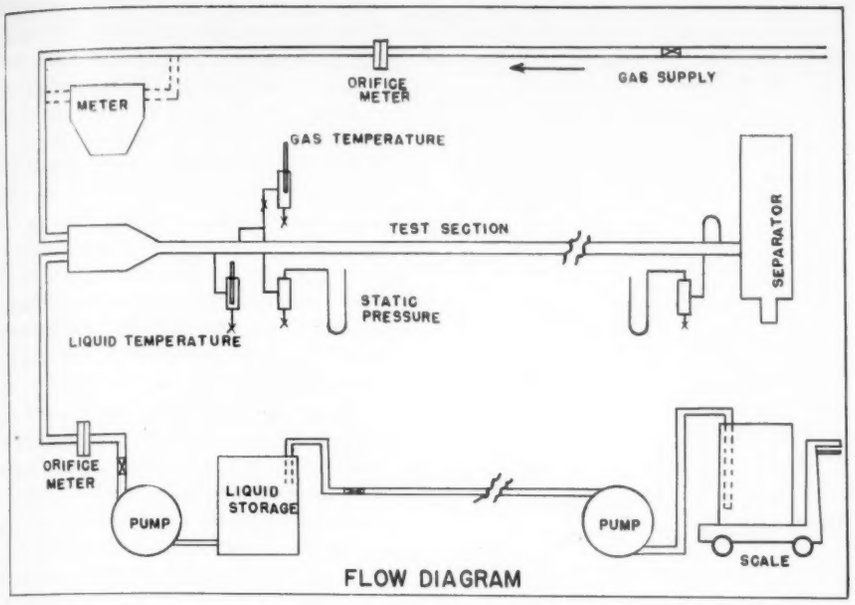


FIG. 1. Flow diagram of the test section of plastic turbing and auxiliary equipment.

of importance. The added pressure drop resulting from a small amount of liquid in the line referred to cannot be accounted for by either of these two reasons, as the diameter loss and the liquid flow is small. Here, the effect of the third factor affecting two-phase pressure drop is evident. As the two phases flow in the pipe there are, in most cases, ripples and waves formed on the surface of the liquid, and the energy expended by the gas in forming these waves is lost and performs no useful work.

The magnitude of the additional pressure drop resulting from the ripple formation was first shown by Boelter and Kepner.[4] They found that when a pipe was wetted with oil and then thoroughly blown down, the pressure drop was approximately 15 per cent greater than in a dry pipe. Alves,[1] while studying two-phase flow in pipe line contactors, compared the power consumed in two-phase flow to the power consumed in agitation and found flow in co-current pipe line contactors to be classified as very intense.

Horizontal two-phase co-current flow has been investigated at the University of California,[9,10,11] University of Delaware,[3,5] Massachusetts Institute of Technology,[6,12] in the Soviet Union,[7,8] and by various engineering research laboratories.[1,2,14]

The first correlation was developed in 1944 by Martinelli et al.[10] Their experimental tests were made with the flow of several liquids and air in tubes ranging in size from capillary tubing to 1-in. pipe. These investigators obtained a relationship that uses empirical constants to correlate their data. Their method of approach was to assume the two-phase pressure drop was related to the pressure drop in the gas phase and the pressure drop in the liquid phase, each calculated by conventional methods assuming that phase to be flowing alone in the pipe.

A further analysis was made by Martinelli and co-workers covering the viscous region in 1946.[11] In 1949, a revised correlation was presented by Lockhart and Martinelli,[9] which included new data covering a wider range of flow rates.

This correlation postulates four flow mechanisms depending on a superficial Reynolds number of the liquid and gas. Separate curves are required for each of the four flow mechanisms.

Jenkins[5] made some interesting observations while attempting to correlate two-phase flow data using Martinelli's parameters. By observing the two-phase pressure drop resulting from the flow of air and water at constant liquid rates, he demonstrated that ϕ_g is not a function of X alone. On a plot of X vs ϕ_g, the data show separate and distinct lines for each liquid rate, crossing the curve of Martinelli. This plot indicates that the Martinelli correlation fits the data $\pm$ 30 per cent due to banding of data rather than that of any one liquid rate following predicted curve.

Bergelin and Gazley[3] also point out that while the Martinelli correlation seems to fit the experimental data + 20 per cent and – 30 per cent, the method of plotting is such that it tends to reduce the spread of data. They suggest that a plot of X^2 vs ϕ^2_g or X vs ϕ^2_g would be more suitable, as ϕ^2_g is directly proportional to the two-phase pressure drop. On such a basis the spread of data would be + 44 per cent and — 50 per cent from the proposed curves.

Baker[2] presented data for flow through 4 to 10-in. diameter pipe lines. The Martinelli type correlation was found to be inadequate for larger diameter lines and also for certain flow patterns. Separate equations for each of the visually observed types of flow were proposed. These equations consist of modifications of the Martinelli equations.

From the above discussion, and considering the fact that various groups have failed to improve the Martinelli type correlation, it appears that a simple analogy to single-phase flow is not capable of describing the pressure drop in two-phase flow. While this correlation has been a great step forward and has served as a valuable tool for design, it now appears that a fresh approach should be tried.

This research project was therefore undertaken to study the visually observed flow types in general and pressure drops resulting from the stable types of two-phase flow over a wide range of variables.

Description of Apparatus

The apparatus consisted primarily of a test section of plastic tubing with all the auxiliary equipment necessary to record flow rates, temperatures, and pressure drops. A general flow sheet of this set-up is shown in Fig. 1.

Most of the previous work has been done in short test sections, some with short visual sections attached. In those cases where visual studies have been made over the entire length of the tube,

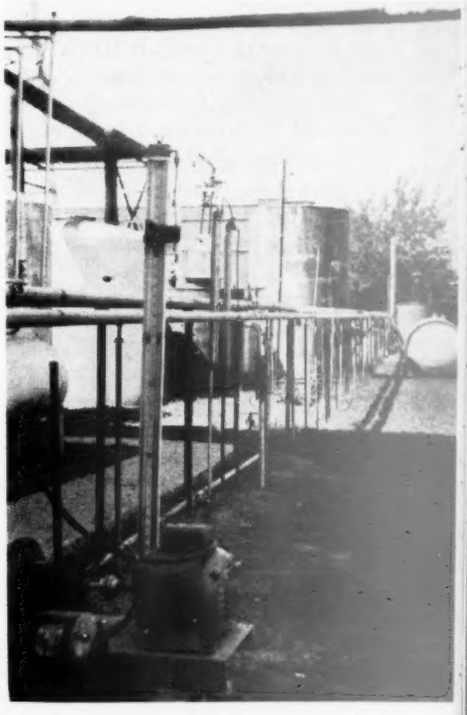


FIG. 2. View of plastic pipe assembly for visual flow studies.

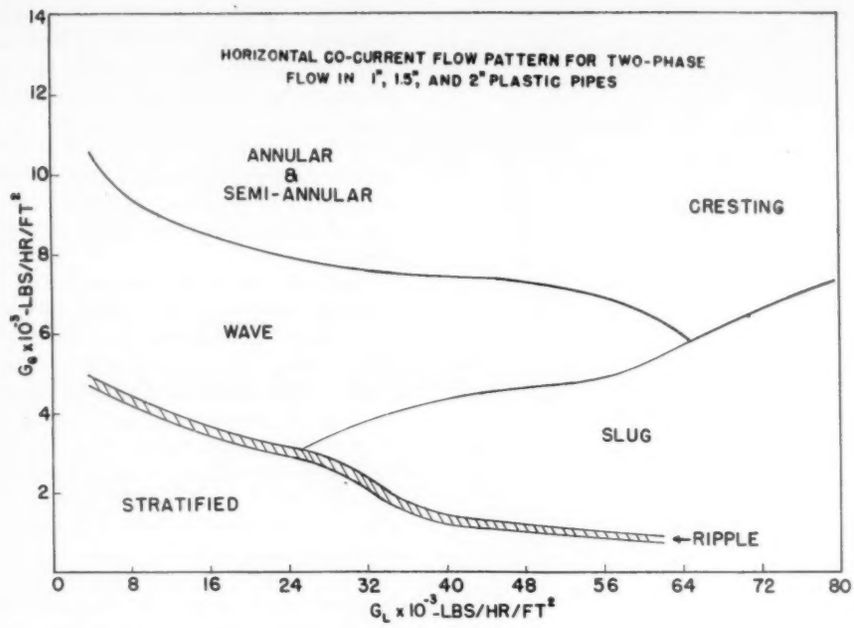


FIG. 3. Results of flow pattern studies.

the visual studies have been separate from the pressure drop tests. There are two serious disadvantages inherent in the type of equipment used by previous investigators: (1) The use of short transparent sections in conjunction with metal pipe causes a flow disturbance just at the point of observation, and (2) the use of two separate sections has the disadvantage of not allowing one to observe the flow characteristics while taking pressure drop data.

For these reasons, a rigid transparent, workable test section of Kraloy plastic tubing was used in this work (Fig. 2). Test sections of 1, 1½, and 2-in. diameter were employed, with an average overall length of 100 ft and an average test section length of 70 ft.

Gas and liquid temperatures were measured by diverting a small amount of the stream into a gas-liquid separator and measuring the temperature of the stream. This procedure was necessary as a thermometer inserted in the stream would disturb the flow pattern. Since splash occurs even at low gas velocities, as soon as the bulb of the thermometer is wet with liquid, the wet bulb temperature of the gas should be read rather than the desired dry bulb temperature.

All pressure drop measurements were made in the gas phase. A small plastic separator was placed between the tube and the manometer. This separator was necessary to clear the manometer lines of any accumulated liquid, and the plastic manometer leads allowed any liquid trapped in the line to be noted.

Flow Patterns

Nomenclature for the various visually observed types of flow is in a state of confusion, as each investigator uses slightly different terms. In order to make clear the nomenclature used in this investigation, a 16 mm color film was prepared. This film is on file at the University of Oklahoma, College of Engineering, School of Chemical Engineering, Norman, Oklahoma, and may be obtained on request.

A brief description of the types of flow classified in this investigation follows: In a horizontal line, with liquid flowing at a constant rate, the following flow types are encountered as the gas rate is increased:

Stratified Flow: This is an unsteady type of flow, due to the presence of an interfacial gradient. This type of flow is characterized by a smooth, undisturbed surface between the two phases.

Ripple Flow: Flow in which the surface is smooth but disturbed by deep slow moving waves. These waves build in amplitude till one eventually closes the tube and forms a slug.

Slug Flow:* An unsteady type of flow in which the liquid closes the entire diameter of the tube and alternate slugs of liquid and gas traverse the tube. The slugs of liquid travel at a greater velocity than the rest of the liquid and accelerate as they move through the tube. At low gas rates the slugs are composed entirely of liquid, while at higher gas rates they contain a considerable amount of froth and bubbles.

Wave Flow:** Flow in which the surface is covered with rough waves that are usually sharply peaked.

Cresting Flow: A rather arbitrary designation used to describe that type of flow characterized by fast moving feathery crests unable to traverse the entire length of the tube without breaking down. It is similar to slug flow, but

*Slug flow does not exist at low liquid rates.
**Wave flow does not exist at very high liquid rates; the flow goes directly from slug to cresting.

FIG. 4. Observed pressure drop in a 1½-in. line at varying liquid rates.

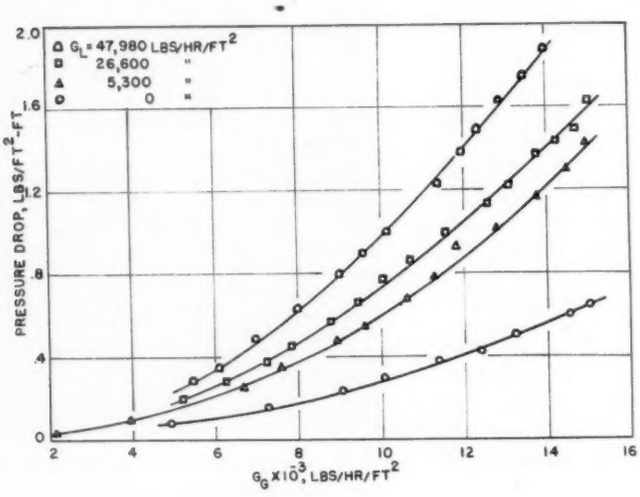
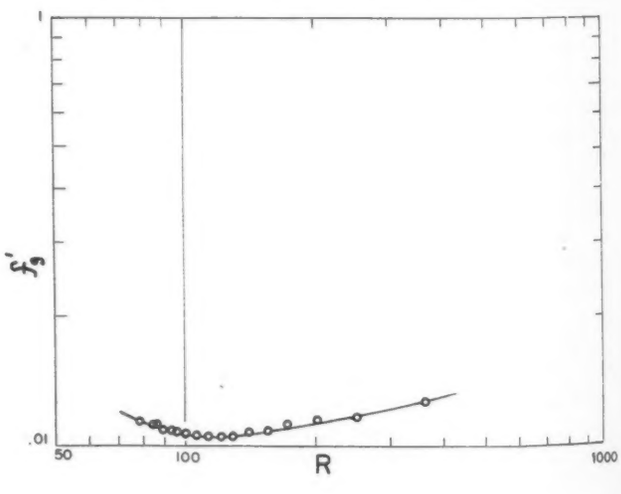


FIG. 5. Constant liquid level rate plotted here uses parameters based on superficial velocities of two phases.



does not have the high pressure fluctuations that slug flow has. This stable pressure drop was the criterion used to designate the change from slug to cresting flow.

Semi-annular Flow: Flow in which the liquid forms a moving film around the inside wall of the pipe and the gas, along with entrained droplets, flows at a high velocity as a central core.

It should be pointed out that even at low gas velocities, resulting in wave flow, a considerable amount of liquid is carried as entrained drops, while in semi-annular flow, a continuous mist is carried in the gas stream. Alves[1] made a few determinations of the amount of liquid entrained as spray by the central gas core in semi-annular flow. He found as much as 37 per cent of the liquid to be carried as spray at a superficial velocity of the gas of 110 ft per second.

Results of the flow pattern studies are shown in Fig. 3. Data for the 1, 1½, and 2-in. line are included in this plot. This investigation was limited to pressures near atmospheric and the validity of the chart at high pressure is doubtful. While high pressure data on the flow patterns would be a great help in predicting two-phase pressure drop, the limitation is not so great as would seem. The correlation to be presented is valid for all types of flow above the ripple and slug types of flow.

Pressure Drop

In Fig. 4, the observed pressure drop in a 1½-in. line for a series of runs is plotted against the mass rate of gas flow, using constant kerosine mass rates as a parameter. From this type of plot it can be seen that the pressure drop increases as the liquid rate is increased. This increase in pressure drop is due not only to the larger amount of liquid being transported, but also as a result of the decreased flow area open to the gas phase and increased wave formation due to the higher gas velocity. It is of interest to note that, starting with the system in wave type flow at a low mass rate of gas and passing into cresting and on to semi-annular flow, there is no sudden change in the rate of increase of pressure drop with increasing gas rate. This sequence would indicate that the transition from wave flow to semi-annular flow is gradual and that the possibility of correlating these types of flow on a single curve might be promising.

When a constant liquid rate line is plotted, using parameters based on superficial velocities of the two phases, as in Fig. 5, the difficulty is obvious. The data fit a single curve by banding on either side of the curve; not by following its true shape. An attempt will be made to explain the shape of the curve qualitatively.

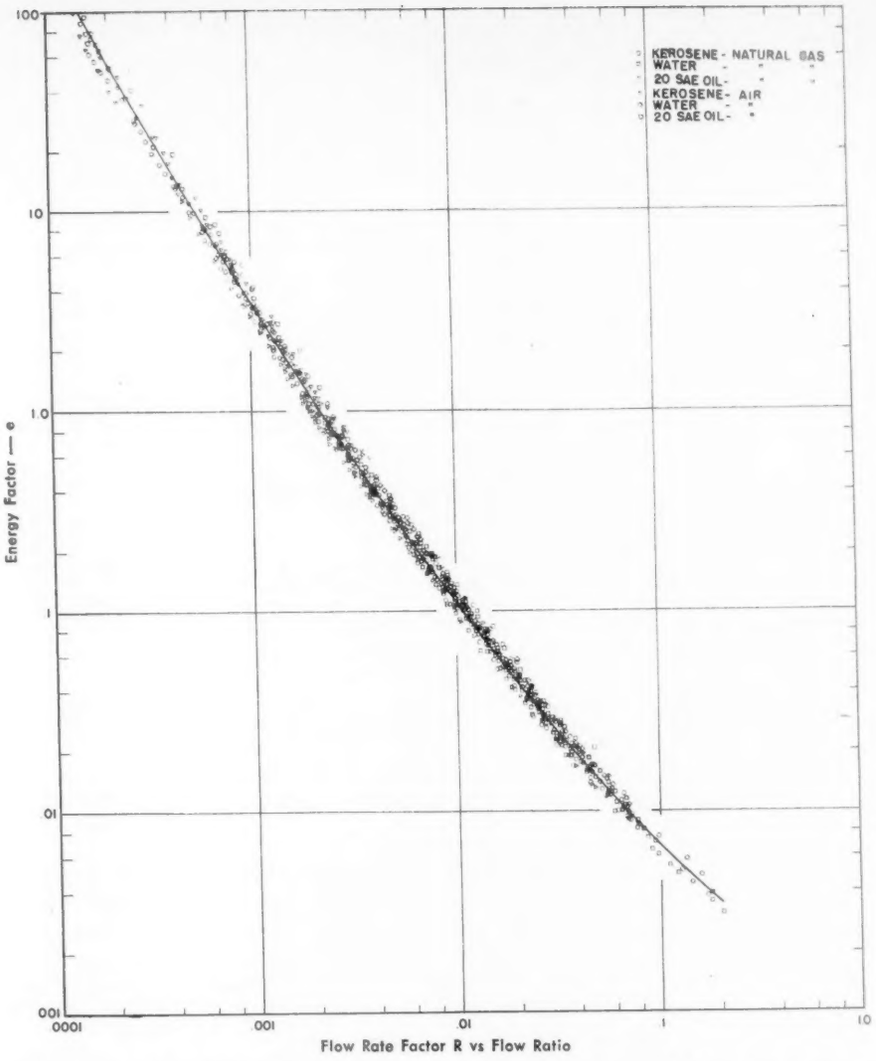


FIG. 6. Results of 1000 experimental runs using three different liquids and two gases on different diameter lines.

Referring to Fig. 5, as the gas rate is increased at constant liquid rate and constant physical properties, the value of the flow ratio is reduced and the curve goes through a minimum. As the gas rate is increased, the liquid level in the tube becomes lower and lower, which gives a larger and larger flow area for the gas phase, resulting in a lower value of f'_g.

At the same time, the crescent shape of the liquid interface develops, and more and more of the tube wall is covered with liquid; ripples form on the liquid surface and increase in magnitude as the gas velocity increases. This ripple formation is the result of irreversible work done on the liquid by the gas. When the increase in irreversible work is greater than the lowering of frictional work due to added flow area, the value of f'_g starts to rise again and continues to rise.

When a series of these constant liquid rates are plotted on this type of chart, a family of curves results in which the locus of minima is shifted. For this reason, it is necessary to find a factor that will straighten the lines in order to correlate the data over a wide range of variables on a single curve.

The problem of correlating the data is basically one of accounting for the

Table 1
Coordinates of Figure 6

ϕ	f	Per cent deviation
.000142	100	....
.0002	53	15.1
.003	26	15.3
.005	10.8	16.2
.0007	6.2	17.7
.001	3.43	19.8
.002	1.16	20.7
.004	.42	19.0
.006	.235	19.1
.01	.114	18.4
.02	.045	16.9
.04	.0187	16.0
.06	.0117	14.5
.1	.0068	12.5
.15	.00445	12.4
.2	.0034	11.8
Avg. . maximum deviation . .		16.4%

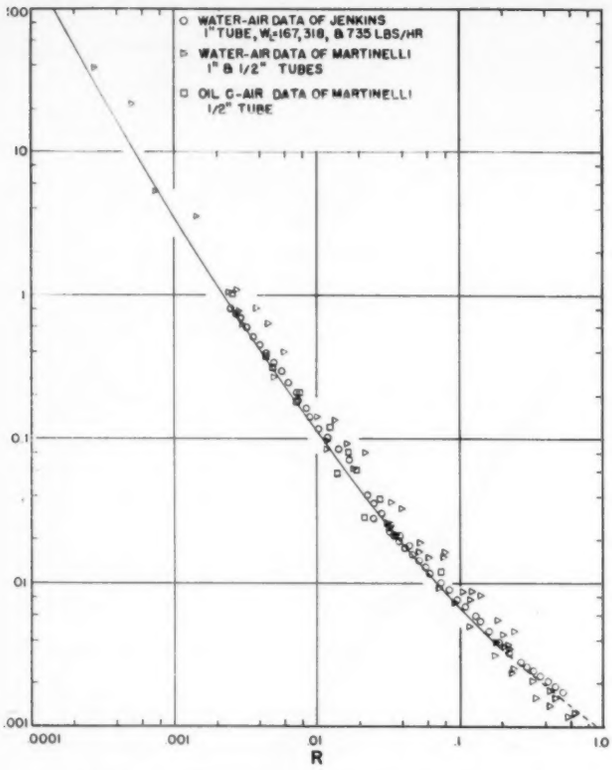


FIG. 7. Comparison of proposed correlation with other data.

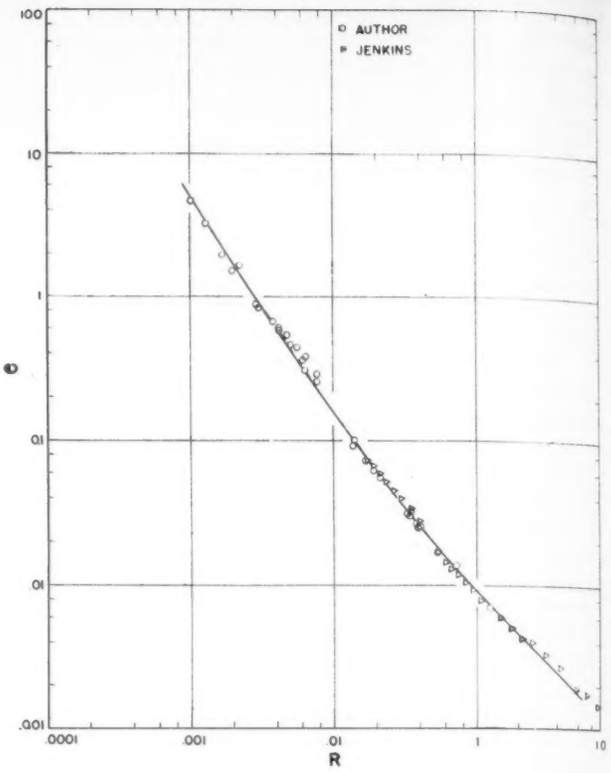


FIG. 8. Ripple flow data.

increase in flow area of the gas phase as the gas rate is increased at a constant liquid rate. This correlation was accomplished by including a ratio, weight rate of liquid to weight rate of liquid plus weight rate of gas, in the denominator of the friction factor group. When this friction factor is plotted against a flow ratio, that includes the physical properties of the gas and liquid and the weight rates of the gas and liquid, parallel curves result, which are almost straight lines.

Mathematically, it is possible to bring the group of lines together at one point. Also, if the terms included in the friction factor are characteristic of the flow, the group of lines will remain together as one line over the entire range.

In order to find the correlation factor necessary to bring the curves together a series of hypothetical runs with the same liquid and gas system at various constant liquid rates was calculated. As the same liquid and gas system was used in each case, the physical properties of the system did not change, the only variable being the mass flow rates.

By including the weight rate of liquid flow to the proper exponent in the friction factor group, all the data for a single system in a given diameter line were found to fall on a single line within the accuracy of the experimental data.

As three different line sizes were used in the experimental work, the effect of pipe diameter was determined by holding all the variables constant except the diameter. The effect of liquid viscosity was determined by using four liquids of different viscosities, and again holding the other factors constant, it was possible to evaluate the effect of liquid viscosity.

In the evaluation of the effect of gas density and gas viscosity, it was impossible to hold all the factors constant as high pressure data were not taken in this work, and the principal difference in gas density occurred between the air and natural gas data. By using the high pressure data of Martinelli[9] and the low pressure data presented here, an approximate value of the exponent to apply to gas density was obtained. Use of this value of the exponent for the gas density permitted evaluation of gas viscosity effect.

The resultant expressions,

$$e = \frac{2g_c D^6 \triangle P \rho_l}{L \dfrac{w_l^{3.6}}{w_l + w_g}} \text{ and}$$

$$R = \left(\frac{w_l}{w_g}\right)^{1.8} \times \left(\frac{\rho_g}{\rho_g}\right)^{0.9} \times \frac{1}{\mu_g^{0.1}} \times \frac{1}{\mu_l^{0.1}}$$

when plotted on log-log paper, represent the experimental data with a maximum deviation of plus or minus 17 per cent. The results of approximately 1000 experimental runs on three liquids, using two gases in different diameter lines is shown in Fig. 6. Coordinates of Fig. 6 are in Table 1.

The 20 SAE oil-natural gas data are excluded, and the validity of the correlation is therefore limited to liquids with viscosities less than 120 centipoises. There is a possibility that the data obtained in the 1-in. test section, using the 20 SAE oil-natural gas system, is not correct due to insufficient time that was allowed for the system to reach equilibrium. The excessive time required to reach equilibrium was noted in the 1½-in. section flowing 20 SAE oil-natural gas, and sufficient time was allowed in that case for the system to stabilize.

Fig. 7 presents a comparison of the proposed correlation with other data from the literature. The agreement of the data of Jenkins[5] is very good; in fact, better than that of this investigation. His experimental accuracy was about plus or minus 3 per cent, while this investigation resulted in data of plus or minus 12 per cent accuracy, due to less extensive equipment.

The data of Martinelli[9] do not fit the proposed correlation as well as do the data of Jenkins. There is no way to check the accuracy of the Martinelli data as it is impossible to determine if it is consistent within itself, since constant gas or liquid rates were not used.

During the investigation, a limited amount of data was observed in the ripple flow range. It was noted that, on the same correlation used for the stable types of flow, the ripple flow data ran consistently about 40 per cent higher in values of "e" for the same flow ratio. These ripple flow data are presented in Fig. 8, while tabulated values of the

coordinates of the curve are given in Table 2. The data of Jenkins[5] for the same type of flow (Jenkins termed this type of flow "wave") are presented on the same curve and are seen to be in very good agreement.

Table 2
Coordinates of Fig. 8 (Ripple Flow)

ϕ	f
.001	5.0
.002	1.7
.004	.6
.006	.33
.01	.16
.02	.063
.06	.026
.1	.016
.2	.009
.4	.0046
.6	.0017

Summary

A tentative flow pattern chart is presented that shows the type of flow that would exist under a given set of mass flow rates. This pattern chart was prepared for different types of flow in a system near atmospheric pressure. Use of the chart at high pressures is not intended or recommended.

An empirical correlation is presented, which allows the two-phase pressure drop to be predicted if the flow rates, physical properties, and pipe diameter are known. This correlation is limited to those flow patterns that are stable in nature; this specifically excludes slug and stratified flow types. The correlation has not been checked with high pressure data. The correlation is limited to liquids with viscosities of less than 120 centipoises.

Systems having pressure drops greater than 10 per cent of the downstream static pressure require stepwise solutions. Stepwise solutions are also required if vaporization occurs in the flow system to any great extent, or if considerable temperature change occurs. Kinetic energy changes, where they are important, must be considered separately.

A tentative correlation is presented to predict pressure drops resulting from ripple type flow. Insufficient experimental data are available to validate this correlation, but it will serve as a guide in estimating the pressure drop in ripple type flow until a better correlation is available, or until sufficient data are available for validation.

Acknowledgment

The authors express their appreciation to F. N. Schneider and G. Barkley, who assisted in obtaining the experimental data, and to the Gulf Oil Corporation for its financial support of the research fellowship, which was held by Philip White.

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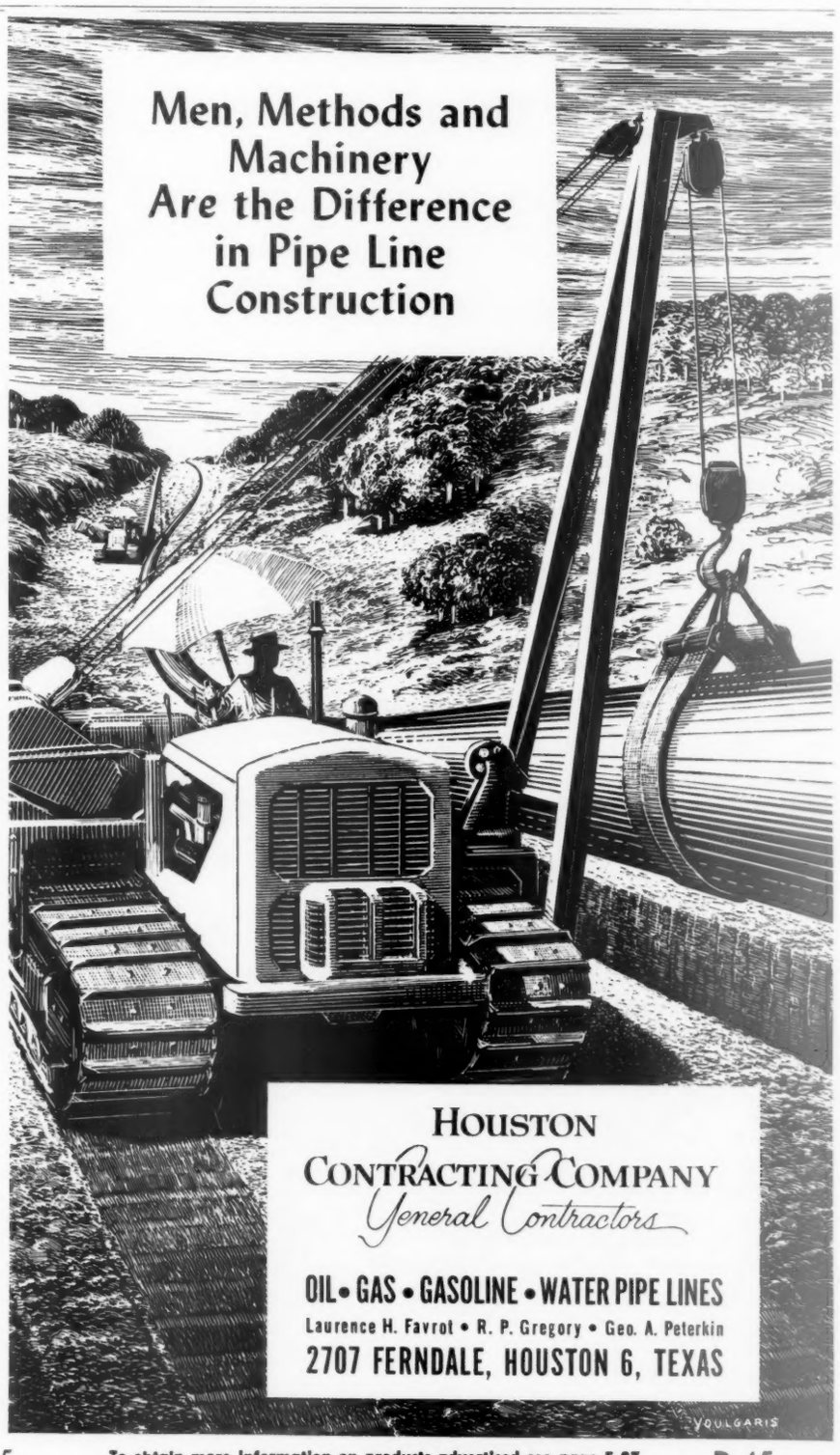
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Underground Gas Storage:

It's Big Business Today, Five-Year Growth Data Shows

H. L. Fruechtenicht
Michigan Gas Storage Company, Jackson, Michigan

UNDERGROUND STORAGE OF NATURAL gas has shown a vast growth in the past five years, statistics compiled by the American Gas Association subcommittee on underground storage reveal.

Here in brief are the highlights of the AGA group's latest annual statistical report, based on information provided by cooperating companies in late 1954.

General Storage Data

Maximum Gas in Storage. The volume of gas in storage on *October 31, 1954* was *1 trillion, 11 billion cu ft.* This volume has risen to 2.45 times the *412 billion cu ft* which was reported for the year 1950. There was an increase over last year of nearly *125 billion cu ft.*

Total Storage Reservoir Capacity (Ultimate Capacity). The ultimate capacity, which includes all native gas remaining in the reservoirs when storage operations were started, has increased 2.40 times for the five-year period. The volume in 1954 was *1 trillion, 859 billion cu ft* as compared to a volume of *774 billion cu ft* in 1950. This volume increased in the past year by nearly *125 billion cu ft.*

Total Output for Year Ending October 31. The nation had a colder winter in 1953-54 and the total output rose from a very low of *232 billion cu ft* in 1953 to *304 billion cu ft* in 1954. The volume has increased for the five-year period since 1950 to slightly more than *2.10 times* the 1950 figure. Inputs for the year 1954 were up about *30 billion* over last year giving a total volume of *432 billion cu ft* into storage for the year.

Maximum Day Output. The maximum day output was also considerably higher this year than the past year because of the colder winter in 1953-54. There was an increase over last year of *1 billion, 351 million cu ft.* In comparing the volume for 1950 to that of 1954, we find that it has risen from *2 billion, 591 million cu ft* in 1950 to *5 billion, 564 million cu ft.* This volume has increased *2.15 times* during the five-year period.

Total Number of Storage Pools. To supplement the statistics on volumes of gas, a review of facilities might be of interest. In 1950 there were *125 storage pools* with *3853 active wells* in comparison to the year 1954 with *172 storage pools* with *6395 active wells.* There are also *12 pools* in the new construction category.

Compressing Stations. On the subject of facilities, it is interesting to note the number of compressing stations used for underground storage of natural gas. There were in 1950, *83 stations* with a total of *158,000 hp.* This is compared with *115 stations* having *300,000 hp* in the year 1954.

Capital Investment. All this growth

Ranking of States in Underground Storage Operations.
(MMcf)
Year 1954

Maximum Gas in Storage		Ultimate Capacity	
Pennsylvania	266,301	Pennsylvania	417,717
Ohio	190,973	Michigan	304,862
West Virginia	160,797	Ohio	292,029
Michigan	91,996	West Virginia	250,568
Oklahoma	77,798	Oklahoma	195,036
Kansas	55,062	New Mexico	119,435
New Mexico	30,475	Kansas	62,602
New York	30,240	California	58,075
Kentucky	19,965	Montana	42,068
Illinois	19,849	New York	35,900
California	18,713	Kentucky	24,833
Montana	14,388	Wyoming	23,896
Wyoming	14,313	Texas	16,640
Texas	11,859	Arkansas	7,801
Indiana	5,507	Indiana	7,073
Arkansas	2,543	Mississippi	865
Mississippi	555	Illinois	—
	1,011,334		1,859,400

Total Output Year Ending October 31		Maximum Day Output	
West Virginia	68,764	West Virginia	1,148
Pennsylvania	59,915	Pennsylvania	1,046
Michigan	49,327	Ohio	824
Ohio	45,677	Michigan	752
Kansas	19,833	Oklahoma	468
Oklahoma	16,576	California	379
California	15,626	Kansas	238
New York	9,366	New York	171
New Mexico	6,519	Illinois	158
Kentucky	5,622	Kentucky	126
Texas	2,061	New Mexico	83
Montana	1,553	Texas	55
Indiana	1,455	Wyoming	36
Wyoming	973	Indiana	36
Illinois	410	Montana	31
Arkansas	389	Arkansas	8
Mississippi	139	Mississippi	5
	304,205		5,564

in underground storage operations has meant a large capital investment. The committee estimates that the total capital investment, which includes both cushion gas and plant, is *$343,000,000* for the year ending October 31, 1954.

Storage Data by States

A few facts regarding storage operations in some of the leading states:

Four Leading States. There are *4* of the *17* states where storage is carried on that are the leaders in all phases of underground storage. These states are West Virginia, Pennsylvania, Michigan, and Ohio. West Virginia is the number one state in outputs both for the maximum day and for the annual total outputs. This is a change from last year when Pennsylvania led in all phases of storage operations. Pennsylvania continues to lead in maximum volume of gas in storage and ultimate capacity. Michigan and Ohio are very close behind in all phases.

Total Annual Output. For the year ending October 31, 1954, West Virginia had an output of nearly *69 billion cu ft* of gas which was the largest volume for any one state. The four states mentioned above which have most of the storage pools in the United States had a total of nearly *224 billion cu ft* or about *75 per cent* of the total.

Maximum Day Output. The four leading states in underground storage had a maximum day output of about *3 billion, 148 million cu ft,* or approximately *70 per cent* of the total of all states. The leader of these is West Virginia with an output of *1 billion, 148 million cu ft.*

Growth of Underground Storage of Natural Gas.

	Volume (MMcf)	% of 1950 volume
Maximum Gas in Storage		
1950	412,106	
1951	546,720	132.7
1952	777,006	188.5
1953	889,138	215.8
1954	1,011,335	245.4
Ultimate Capacity		
1950	774,434	
1951	915,988	118.3
1952	1,292,321	166.9
1953	1,735,815	224.1
1954	1,859,398	240.1
Total Output Year Ending October 31		
1950	143,435	
1951	200,435	139.7
1952	234,792	163.7
1953	232,559	162.1
1954	304,205	212.1
Maximum Day Output		
1950	2,591	
1951	3,241	125.1
1952	4,101	158.3
1953	4,213	162.6
1954	5,564	214.7

Acknowledgment

This article abstracted from a report presented at the AGA Gas Supply, Transmission, and Storage Conference, Pittsburgh, Pennsylvania, May 9-19, 1955.

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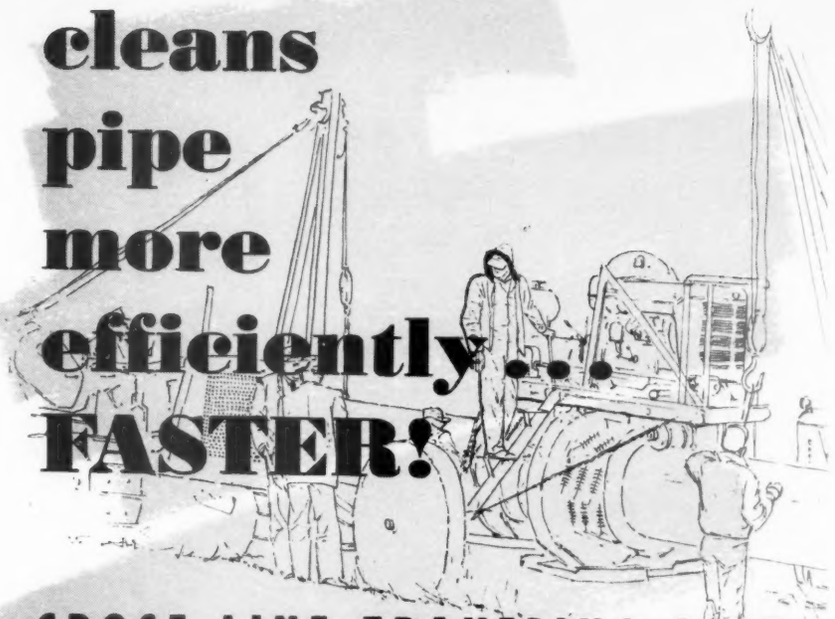

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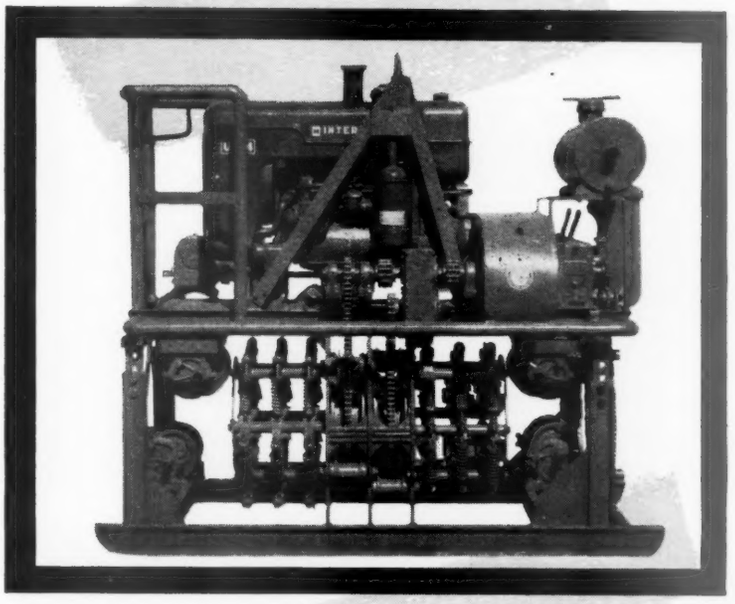

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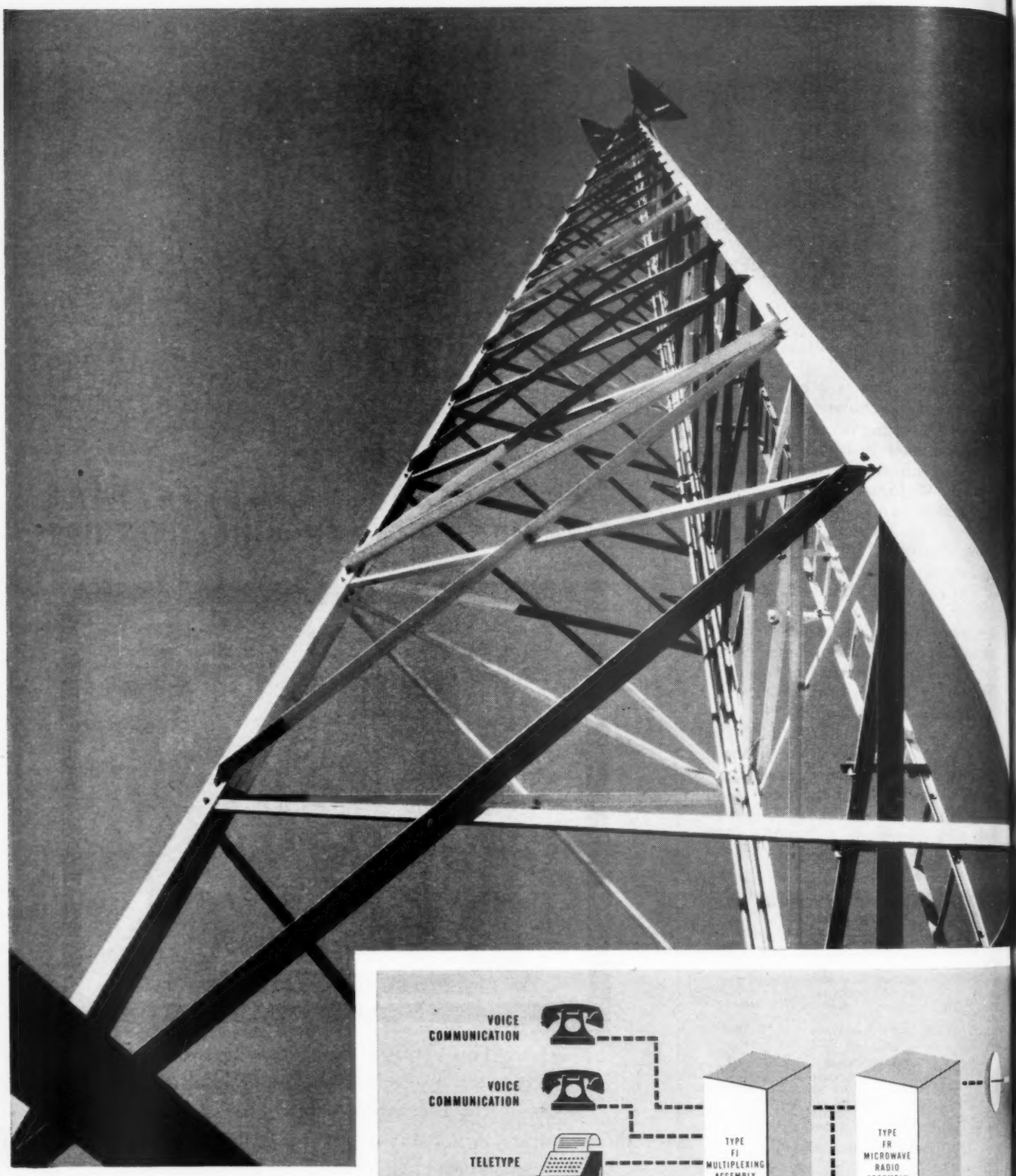

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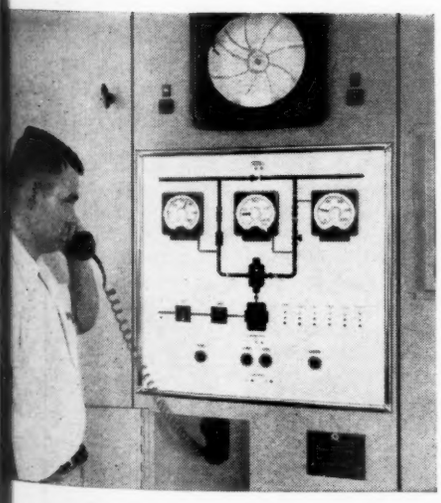

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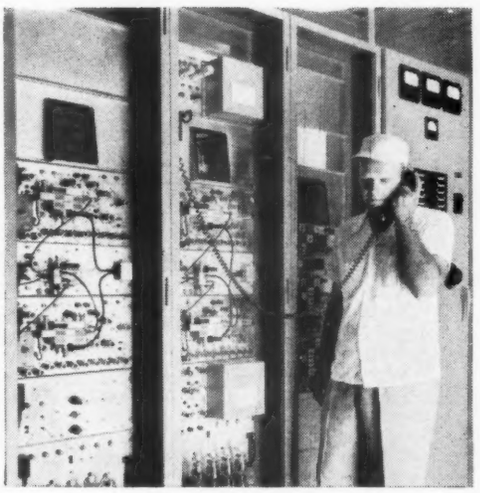

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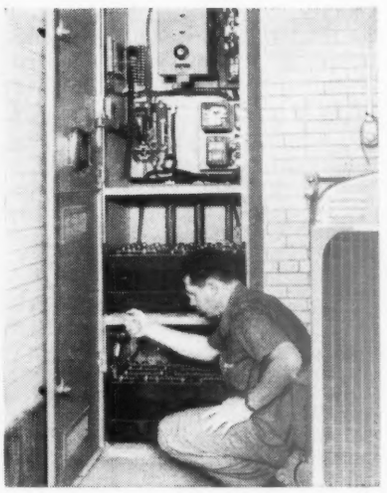

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PIPE LINE PERSONALS

▸ **C. C. Combs** has been elected a vice president of Shell Pipe Line Corporation. A native of Everett, Washington, he joined the Shell organization in 1923 as a service station attendant in California. In 1927 he was named an auditor in the financial organization and rose through positions of increasing responsibility in the Los Angeles, San Francisco, and Honolulu marketing divisions and at the Martinez, California, refinery.

He was named assistant corporate secretary of Shell Oil Company in 1940 and added the duties of assistant treasurer in 1942. He became assistant treasurer and assistant controller in the San Francisco office in 1949. Since 1950 he has been on various special assignments, including three years as controller of Shell Oil Company of Canada, Ltd.

Combs will be at Shell Pipe Line's head office in Houston.

▸ **N. P. Chesnutt,** chief engineer for the Southern Union Gas Company, headquarters in Dallas, has been awarded a diamond-studded lapel pin in recognition of twenty continuous years of company service.

N. P. Chesnutt

During his years with Southern Union, Chesnutt has acted as meter man, district engineer in West Texas, field engineer in West Texas, field superintendent in Farmington, New Mexico, and engineer in Dallas. Chesnutt is now in charge of the engineering department which includes the designing and planning of transmission and distribution pipe lines, compressor stations, dehydration plants and treating plants.

▸ **Harold S. Walker, Jr.,** formerly of Lit Bros., Philadelphia, has been appointed secretary of the General Management Section of the American Gas Association. He succeeds **Harrington A. Rose,** who resigned to join the Transcontinental Gas Pipe Line Corporation.

Walker was born in Philadelphia and was graduated from the United States Military Academy at West Point, New York, in 1943 with a BS degree. He received an MA degree in 1953 from Columbia University.

▸ Three Interstate Oil Pipe Line Company employees, each of whom has completed more than 40 years of service with the company without experiencing a lost time industrial injury, were accorded special safety achievement recognition recently. Honored were **J. B. Barnett,** district superintendent of Interstate's Lake St. John, Louisiana, district; **R. L. Holman,** station chief engineer of Weller Station, near Homer, Louisiana; and **E. E. Wasson,** station chief engineer of Finney Station, near Shreveport. The special recognition consisted of individual certificates of honor from the Joseph A. Holmes Safety Association, the national organization dedicated to the promotion of safety in the mining and mineral industries.

Several organizational changes have been announced recently by Interstate Oil Pipe Line Company. **Bruce Ramsey,** former vice president and general manager, has been appointed to the position of operations consultant to the president. He will continue to serve as a member of Interstate's board of directors.

W. F. Davis, assistant general manager since July 1, 1953, and a Director of the company since February 1, 1955, has been elected vice president and General Manager to succeed Ramsey. **J. D. Toler,** assistant secretary, has been elected to the additional position of assistant treasurer.

J. M. Bradley, a director and former northern division manager, has been named assistant general manager directly responsible for the activities of Interstate's engineering, material-traffic and oil movements departments. **S. A. Sheppard,** acting general superintendent, has been named general superintendent of the company's crude oil pipe line operations. **S. Brown** will be responsible as director for the activities of employee relations, public relations and medical department. **W. L. Bassmann,** former assistant manager of the employee relations department, has been named manager of that department. **O. R. Bates** will continue in charge of public relations with the new title of public relations manager.

▸ **E. F. Hindman,** former general superintendent of two south Louisiana subsidiaries of Texas Gas Transmission Corporation, has been named manager of the newly-created Louisiana division of the company. Hindman, a veteran of 25 years in the natural gas business, joined Louisiana Natural Gas Corp. as pipeline superintendent in June, 1949 after 20 years with Arkansas-Louisiana Gas Corporation. He was appointed general superintendent of Louisiana Natural in July, 1950, and also of Texas Northern when that company was formed as a subsidiary of Texas Gas.

E. F. Hindman

▸ Appointment of **J. N. Carpenter** of Dallas as superintendent of Lone Star Gas Company's pipe line department has been announced. Carpenter, advanced from assistant pipe line superintendent, succeeds **Luther Tolbert** who has retired from active duty under advice of his physician.

Carpenter began his career with Lone Star in 1927 as a welder and a few months later was named welder foreman. In 1932 he was appointed assistant foreman for the Fort Worth pipe line district, and in 1935 was placed in charge of the Gainesville pipe line district. Eleven years later he was appointed foreman at Ranger and held that post until 1948 when he became assistant superintendent of the pipe line department.

Tolbert began his career with Lone Star as laborer in 1920 and in August of 1921 was assigned to driving a truck for the pipe line department.

F. G. White

S. L. Westlake

▸ The advancement of two members of the Magnolia Pipe Line Company organization has been announced. **Stanley L. Westlake** has been appointed chief engineer and **F. G. White** has been named division superintendent of the northern division at Oklahoma City. Westlake succeeds the late **John G. Norton,** who was Magnolia Pipe Line Company's chief mechanical engineer. He joined Magnolia after having served as a special pipe line consultant for the Petroleum Administration for War and as an engineer for various other pipe line companies including an assignment helping design the Iraq pipe line system in the Middle East. White succeeds **O. M. Joy,** who has retired. He moves up from his present position as assistant division superintendent at Oklahoma City. In the past he has served in supervisory capacities at Brownfield and Luling, Texas, and at Salem, Illinois.

▸ **R. W. McDowell,** Tulsa, Oklahoma, president of D-X Sunray Oil Company, has been elected a director of Great Lakes Pipe Line Company, Harry Moreland. president of the products pipe line carrier has announced. McDowell succeeds **Jacob France** who resigned after having served as a Great Lakes director since 1931, the year the company began operation. For many years France was president of Mid-Continent Petroleum Corporation and later was chairman of its board of directors.

▸ Appointment of **H. G. Mariner** to succeed **C. M. Scott, Jr.** as general manager of the Service Pipe Line Company has been announced. Scott, after almost 39 years of service with the Company, much of it as a director, retired June 25. Like Scott, Mariner is an engineer. After service in South America with the Lago Petroleum Corporation, and a period with the Kansas State Highway Commission and the Phillips Petroleum Company, Mariner joined Service Pipe Line Company as a draftsman and instrument man in 1940, and has grown with the company since.

In point of service the oldest member of the board of directors, Scott joined the company in Tulsa in 1916 as an engineer-draftsman.

H. G. Mariner

C. M. Scott, Jr.

XUM

▸ **L. A. Foy** has been named district superintendent of Magnolia Pipe Line Company's West Texas district, with headquarters at Midland. He was formerly chief gager of the western division. He replaces **R. W. Stewart,** who has been transferred to Socony Mobil Oil Company, Inc. Stewart will go to Iran on a loan basis to Socony Mobil as pipe line operating engineer, and will have supervision over operations and maintenance of the main crude oil pipe line system from the Iranian oil fields to the Abadan Refinery and the Mashur loading terminal.

Other recent changes in Magnolia Pipe Line Company include **Clyle R. Smith** promoted to chief gager of the western division at Midland. He was formerly gager foreman at Snyder, Texas. **A. G. Schwarz** has been named gager foreman at Sweetwater, Texas, and **R. L. Smith** gager foreman at Snyder. **John R. Whorton** has been promoted to chief delivery gager at Midland. He was formerly field gager in the North Basin district.

R. L. Phillips has been transferred to Brownfield, Texas, as assistant district superintendent of the North Basin district. He formerly held the same post in the West Texas district, at Snyder. **F. G. White** has been promoted to assistant division superintendent of the Northern division at Oklahoma City. He was formerly district superintendent of the North Basin district.

A. W. Butler has been promoted to district superintendent at Brownfield, Texas. He was formerly assistant district superintendent of the North Basin district. **M. E. Bay** has been transferred to Corsicana as district superintendent of the Dallas district, replacing **C. E. Still,** who has retired. **J. R. Dean** has been promoted to district superintendent of the North Texas district at Wichita Falls. **W. M. Harris** has been transferred to Snyder as assistant district superitendent of the West Texas district.

▸ **R. V. Lahr** has been named to head the newly created field operations department of Shell Pipe Line Corporation. Lahr has been with Shell Pipe Line for twenty-two years and has served in all areas in which the company operates. His past experience includes duties as electrical engineer, corrosion engineer, assistant area manger, an darea manager, and most recently as assistant to vice president.

▸ **Royce Cox** has been named assistant purchasing agent in charge of purchasing materials for compressor station operations and construction for Texas Gas Transmission Corporation, Owensboro, Kentucky. **B. L. Cooper,** formerly assistant expediter, has been promoted to expediter for Texas Gas. **Robert T. Robinson,** former supervisor of construction accounting, has been promoted to assistant manager of plant accounting in charge of construction and plant ledgers.

J. W. Carneal

▸ **James W. Carneal,** formerly assistant superintendent of Texas Gas Transmission Corporation, pipe line department, has been appointed industrial representative for the firm's sales and customer relations department.

▸ **Burt Hull,** veteran pipeliner, has been named associate and consultant for Walnesco Hydraulic Pipeline Testing Service, with headquarters in Dallas.

George White

John Talbot

▸ **John Talbot** has been named compressor superintendent and **George White** has been named assistant compressor superintendent of Tennessee Gas Transmission Company. Talbot joined TGT in 1943, during formation of the company. He was promoted to division superintendent in 1945 and promoted to assistant compressor superintendent in 1948. White, formerly engineer in the compressor section of TGT's operating department, is a graduate of Rice Institute. Talbot succeeds **R. V. Mertz,** former compressor superintendent, who is devoting full time to engineering and production activities of a Houston butadiene plant whose purchase from the government by TGT and Food Machinery and Chemical Corporation is expected to be completed shortly.

▸ **John M. Winters, Jr.,** has been elected president and treasurer of the Transok Pipe Line Company, recently organized in Tulsa. The new company will operate an intrastate gas pipe line in Oklahoma. Other officers of the new pipe line company are **Roger S. Randolph** and **Horace D. Ballaine,** vice presidents; **C. C. Killin,** vice president, secretary, and assistant treasurer; **J. R. Ryan,** assistant secretary; and **P. H. Kuper,** comptroller.

▸ **J. T. Simon** has been named a vice president of Mountain Fuel Supply Company, with general supervision of the firm's pipe line operations, and will headquarter in the company's Rock Springs, Wyoming, office.

▸ **William S. Spangler,** general superintendent, and **Charles E. Shaver,** company attorney, have been elected directors of Humble Pipe Line Company.

▸ **Harry McLeod** has been named superintendent of the crude oil pipe line division of Arkansas Fuel Oil Corporation, Shreveport.

▸ **W. R. Johnston,** formerly with Humble Oil and Refining Company in Midland, has been named manager of production operations for the Pacific Northwest Pipeline Corporation, Houston. His headquarters will be in Albuquerque.

▸ It has been announced by the American Oil Pipe Line Company (previously Pan American Pipe Line Company), that **Joseph R. Burdette** who has been serving as mechanical engineer in the headquarters office of the American Oil Pipe Line Company in Houston, has been promoted to division engineer in the West Texas division, with headquarters at Snyder, Texas.

▸ **Carl K. Mount** has joined Transcontinental Gas Pipe Line Corporation as gas contract representative in the gas supply department. He entered the oil field business in 1930 and has spent 23 years in drilling, production, sales, land, and lease work. Before joining Transcontinental he was an independent grease broker, in the firm of Simpson and Mount.

▸ **William R. Connole,** of West Hartford, Connecticut, took office recently as a member of the Federal Power Commission for the term expiring June 22, 1960. Connole, who succeeds Commissioner **Nelson Lee Smith,** was nominated to the Federal Power Commission by **President Eisenhower.** The nomination was unanimously confirmed by the Senate on May 2. Connole has been chief legal officer of the Connecticut Public Utilities Commission since 1950.

▸ **Wallace W. Mitchell** has been named to the newly created post of general superintendent of Tide Water Associated Oil Company's western pipe line department. He will be in charge of the company's 789 miles of crude line in the San Joaquin Valley and the Los Angeles, California, areas. **William S. Davidson, Jr.,** has been appointed superintendent of the San Joaquin Valley district, the position formerly held by Mitchell.

Price Safety Record Honored by Council

One of the industrial awards of the National Safety Council and the first such award ever won in the field of pipe line construction has been presented to H. C. Price Company, Bartlesville, Oklahoma.

The National Safety Council presented H. C. Price Company with its Certificate of Commendation in recognition of the achievement of one of its five pipe line construction units, headed by Superintendent R. L. Ezell, which worked a total of 434,528 manhours without a single disabling injury for the period November 20, 1953 to December 31, 1954, and which set a new record for the industry.

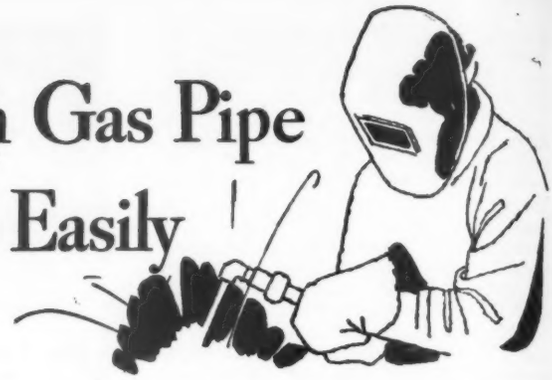
Trans-Prairie Extends Pipe Line System

Trans-Prairie Pipelines, Ltd., which operates the gathering system in the Daly, Virden-Roselea, and North Virden oil fields of southwestern Manitoba, Canada, has completed extensions to its line that raise total mileage to 25 miles of main line and 20 miles of laterals. It has also installed several new low-cost centrifugal booster pumps to handle individual batteries in groups of from three to five or six around a central pump of high pressure piston type.

The company contracted 7½ miles of line in the winter and pipe was strung on the frozen ground as a economy measure. After the spring thaw and road bans were over, the right-of-way was ditched and the pipe laid more quickly than could have been done in the conventional manner, having regard to the normally soft condition of access roads in the summer.

At present Trans-Prairie is constructing 3 miles of 4-in. line for five new batteries at the northwest end of the North Virden field, and has completed laying 2 miles of 4-in. at the southeast end of the Virden-Roselea field.

Bethlehem High-Strength Gas Pipe Resists Fatigue—Welds Easily



Bethlehem High-Strength Gas Pipe is recommended for pipe-line compressor stations and other locations where severe vibrations or extremely high pressures are encountered.

This pipe is fabricated from as-rolled plates of Mayari R, Bethlehem's high-strength low-alloy steel. Mayari R has a yield point of 50,000 psi min, an endurance limit of approximately 50,000 psi, high corrosion resistance and excellent workability and weldability.

RESISTANCE TO FATIGUE—Mayari R steel's endurance limit is unusually high—about 50,000 psi (60 to 75 pct of its tensile strength of 70,000 psi minimum). In addition, Mayari R steel is extremely ductile, with 22 pct minimum elongation in 2 in. Pipe fabricated from Mayari R plate has the exceptional endurance strength, extreme ductility and high impact qualities needed for handling vibration, pulsation and variable shock-loadings.

LIGHTER WALLS—When you use Bethlehem High-Strength Gas Pipe you can specify much lighter walls than with ordinary carbon-steel pipe. This results in savings in material, as well as in the cost of transportation, handling and field welding.

WELDS READILY—Bethlehem High-Strength Gas Pipe is readily welded by following normal field-welding procedures, using mild steel electrodes.

FOR NORMAL PIPELINE SERVICE we recommend Bethlehem Gas Pipe fabricated from carbon steel, meeting specifications ASTM A134 or API 5LX42. Comparative weights and test pressures for these grades of pipe, as well as for pipe made from Mayari R, are shown in the table below.

All grades of Bethlehem Gas Pipe are made in 40-ft lengths, with beveled or square ends, and in all diameters from 18 in. OD. We can grit-blast, prime, coal-tar enamel and wrap the pipe to your specifications.

A phone call or letter to the nearest Bethlehem sales office will bring you full information about Bethlehem Gas Pipe, in Mayari R or carbon-steel grades.

Comparative Maximum Test Pressure: MAYARI R, API 5LX42 and ASTM A134 Steel Pipe

Pipe OD In.	¼ IN. THICK				⅜ IN. THICK				½ IN. THICK				¾ IN. THICK				1 IN. THICK			
	Wt lb per ft	Test Pressure psi Mayari R	API 5Lx42	ASTM A134*	Wt lb per ft	Test Pressure psi Mayari R	API 5Lx42	ASTM A134*	Wt lb per ft	Test Pressure psi Mayari R	API 5Lx42	ASTM A134*	Wt lb per ft	Test Pressure psi Mayari R	API 5Lx42	ASTM A134*	Wt lb per ft	Test Pressure psi Mayari R	API 5Lx42	ASTM A134*
18	49	1180	990	665	73	1770	1490	960	96	2360	1985	1275								
20	54	1120	920	575	81	1590	1340	860	107	2130	1785	1150								
22	63	965	820	520	93	1450	1220	815	118	1935	1630	1040								
24	67	885	750	475	99	1330	1120	745	130	1770	1490	955								
26	73	820	690	440	107	1225	1030	690	141	1635	1380	880	202	2450	2050	1325				
28	79	760	640	405	117	1140	955	640	153	1515	1275	820	219	2270	1910	1225				
30	85	710	595	380	125	1060	895	600	164	1415	1190	765	235	2130	1785	1145				
32	92	665	560	355	134	1000	835	560	176	1325	1115	715	252	1990	1675	1075	330	2650	2230	1430
34	97	625	525	335	143	940	785	505	187	1250	1050	675	268	1875	1575	1010	352	2500	2100	1350
36	105	590	495	315	152	885	750	480	200	1180	980	635	285	1770	1490	950	374	2360	1980	1275
42	118	505	425	270	173	760	640	410	228	1010	850	545	334	1525	1275	815	440	2020	1700	1090
48	135	440	375	235	199	665	560	360	263	885	745	475	384	1325	1115	715	506	1770	1485	955
60	170	355	300	190	252	530	450	285	331	710	595	380	483	1060	890	570	638	1415	1190	765
72	210	295	250	160	306	440	375	240	403	590	497	320	582	885	740	475	770	1180	990	635
84	238	250	215	135	353	380	320	205	464	505	425	270	672	755	635	410	902	1010	850	545

*ASTM A283 Grade B, to be used when ordering to ASTM A134 Specification. If ASTM A283 Grade C is used instead, the test pressures may be increased by 11 pct. Pipe can be furnished in diameters intermediate to those shown above.

Test pressures above are based on stressing steel to 85 pct of minimum yield point
Mayari R—85 pct of yield point = 42500 psi
API 5LX42—85 pct of yield point = 35700 psi
ASTM A134—85 pct of yield point = 22950 psi
Formula used: $P = \frac{2ts}{D}$

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Pipe Line Projects

Texas Eastern Contracts for Line, Station Construction Total $70,883,000

Contracts have been awarded by Texas Eastern Transmission Corporation for the construction of facilities certified by the Federal Power Commission to permit the company to maintain its natural gas delivery capacity after the reconversion of the major portion of the Little Big Inch pipe line from natural gas to petroleum product service. Contracts for the pipe line construction were awarded with the project divided into six spreads and five river crossing jobs. Brown and Root, Inc., of Houston will provide field supervision for the pipe line work and will, with its own crews, construct the compressor stations.

Over-all cost of the new natural gas facilities is estimated at $70,883,000, which, in addition to a new 30-in. pipe line, includes eight new compressor stations, 100 miles of additional lateral and connecting smaller diameter lines, and the addition of compression to certain existing stations. These new facilities will increase the capacity of Texas Eastern's 30-in. pipe line by an amount equal to that now being carried by the Little Big Inch (approximately 200,000,000 cu ft a day).

The approved project calls for a new 30-in. pipe line, which will extend some 377 miles in a generally northeasterly direction from the company's existing line near Beaumont, Texas, through southern Louisiana, southern and central Mississippi, to a point of connection with the southern terminus of the company's existing 30-in. pipe line at Kosciusko, Mississippi.

The route of the pipe line crosses four large rivers and one bayou, the Neches, the Sabine, the Atchafalaya, and the Mississippi rivers, and Bayou Courtableau. In each case for added protection two lines will be laid under the rivers.

The new compressor stations will have a total of 91,400 hp. These new compressor stations plus the installation of 36,020 additional horsepower in Texas Eastern's existing stations will produce a total of 127,420 hp.

Two new reciprocating compressor stations will be installed in Texas, one near Booth, and another near Vidor. The Booth station will be powered by two 1100-hp reciprocating engines. The Vidor station will use five 1000-hp reciprocating units. In addition, an 8800-hp reciprocating compressor station will be constructed near Holbrook, Pennsylvania. New electric motor driven centrifugal stations will be built at Egypt, Mississippi, Mt. Pleasant, Tennessee, and Tompkinsville, Kentucky. Each of these stations will contain one 15,000-hp electric motor driven centrifugal compressor unit. Two gas turbine centrifugal stations, located at Athens, Ohio, and Owingsville, Kentucky, will be included in the new system. Each of these stations will contain two 7600-hp gas turbine centrifugal compressors.

In addition to the new stations, present construction plans call for the addition of some 36,020 hp at existing stations. Additional reciprocating compressors will be added at Kosciusko, Mississippi, and Danville, Kentucky; the Kosciusko station receiving a 5000-hp increase and the Danville station receiving a 3520-hp increase. Additional centrifugal horsepower will be added as follows: Barton, Alabama, 7500 hp; Gladeville, Tennessee, 7500 hp; Wheelersburg, Ohio, 7500 hp, and Berne, Ohio, 5000 hp.

Contracts for the pipe line construction have been let, and the approximately 377 miles of 30-in. pipe line to be built has been divided into six jobs as follows:

Job No. 1: Begins at Texas Eastern's compressor station near Beaumont, Texas, extending northeasterly approximately 59 miles to a point approximately 12 miles east of DeQuincy, Louisiana. To be constructed by the Houston Contracting Company, Houston, Texas.

Job No. 2: Begins at a point approximately 12 miles east of DeQuincy, extending northeasterly approximately 63 miles to a point approximately 10 miles west of Opelousas, Louisiana. To be constructed by the Tulsa Williams Company, Tulsa, Oklahoma.

Job No. 3: Begins at a point approximately 10 miles west of Opelousas, and extends northeasterly approximately 55 miles to a point on the west side of the Mississippi River approximately 5 miles east of New Roads, Louisiana. To be constructed by the Tulsa Williams Company, Tulsa, Oklahoma.

Job No. 4: Begins at the east side of the Mississippi River approximately 6 miles east of New Roads, and extends for a distance of approximately 65 miles to a point approximately 1 mile west of Bude, Mississippi. To be constructed by the H. C. Price Company, Bartlesville, Oklahoma.

Job No. 5: Begins at a point approximately 1 miles west of Bude, Mississippi, and extends in a northeasterly direction approximately 69 miles to a point approximately 2 miles southeast of Clinton, Mississippi. To be constructed by the H. C. Price Company.

Job No. 6: Begins at a point approximately 2 miles southeast of Clinton, Mississippi, and extends northeasterly approximately 64 miles terminating at Texas Eastern's compressor station near Kosciusko, Mississippi. To be constructed by H. B. Zachry Company, San Antonio, Texas.

River Crossings: Neches River to be installed by Pentzien, Inc., Omaha, Nebraska. Sabine River to be installed by Missouri Valley Dredging Company, Omaha, Nebraska. Mississippi River to be installed by J. Ray McDermott Company, Harvey, Louisiana. Bayou Courtableau to be installed by Missouri Valley Dredging Company. Atchafalaya River to be installed by Pentzien, Inc.

PG&E Asks Permit for $24,000,000 Line Project

Plans for a $24,000,000 enlargement of facilities to import more natural gas for customers of Pacific Gas and Electric Company were disclosed in San Francisco when the company filed an application with the California Public Utilities Commission for authorization to begin the project.

The project would ultimately result in bringing an additional 225,000,000 cu ft of natural gas a day into northern and central California from Texas and New Mexico fields. This would increase the PG&E's daily importation of 925,000,000 cu ft by January 1, 1959.

A series of paralleling sections of pipe, adjacent to the existing 502-mile "Super Inch" line between Topock, Arizona, and Milpitas, California, would virtually complete the construction of a second 34-in. diam high-pressure system between those two points. Already, 283 miles of parallel line has been laid in projects that raised the "Super Inch" capacity from its original 400,000,000 cu ft a day to the present 700,000,000 cu ft. The project now before the state commissioner would add 189.8 miles of paralleling sections.

An agreement between PG&E and the El Paso Natural Gas Company, which formed the basis of the company's application, calls for the delivery of the first additional 50,000,000

cu ft by November 1, 1956. Another 75,000,000 cu ft would be delivered beginning November 1, 1957, and 25,000,000 cu ft more by January 1, 1958. The remaining 75,000,000 cu ft would be taken by PG&E by January 1, 1959.

A construction program to meet these increases would provide the required additional pipe line capacity in time for each increase in delivery. Additionally, the capacity of two compressor stations along the "Super Inch" route would be increased by a total of 12,500 hp, to maintain transmission pressures, making the compressor capacity total 79,360 hp.

Certificate Issued For Short Gas Line

The Federal Power Commission has issued certificates to the Clinchfield Coal Corporation, of Dante, Virginia, and Kentucky West Virginia Gas Company, of Ashland, Kentucky, authorizing sales of natural gas by the coal company to the pipe line company, and the construction of 32 miles of line by Kentucky West Virginia for transportation of the gas it will purchase from Clinchfield together with other appurtenant facilities.

New Facilities Planned For North Central Ohio

The Ohio Fuel Gas Company, of Columbus, Ohio, has filed an application with the Federal Power Commission requesting authority to construct approximately 19 miles of natural gas pipe line and a new metering station in north central Ohio.

The project would include 18.9 miles of 16-in. line in Hardin and Allen counties, partially paralleling an existing line and connecting it with a proposed metering station at Lima to deliver additional gas to West Ohio Gas Company. Ohio Fuel also proposes to build a new metering station near a new petrochemical plant of Standard Oil Company of Ohio at Lima.

Great Lakes to Lay 106 Miles of Line

Great Lakes Pipe Line Company will increase capacity of its system between Des Moines and Iowa City by construction of a 12-in. line, Harry Moreland, company president, has announced.

The 106-mile line, powered at Des Moines, will parallel existing 6 and 8-in. lines and will be completed prior to the fall heating system.

The three lines east of Des Moines serve company terminals at Iowa City and Chicago and connected terminals at Amboy, Illinois, and Madison, Wisconsin.

California Standard to Enlarge West Texas Line

Standard Oil Company of California has announced plans for enlargement of its West Texas pipe line facilities to a 20-in. line with an ultimate potential capacity of 220,000 bbl of crude oil daily delivered to El Paso.

T. S. Petersen, president, explained that in an emergency the expanded line could make crude oil available to be shipped to California over the Southern Pacific Pipe Lines, Inc., petroleum products line now under construction. The Southern Pacific Pipe Lines route will extend from El Paso to Phoenix, and from the Los Angeles basin to Phoenix. Petersen pointed out that in an emergency the flow over the Los Angeles-Phoenix link could be readily reversed, so that the crude oil could flow directly into Southern California.

Petersen said Standard subsidiary, Pasotex Pipe Line Company, will begin construction of the first stage immediately, at a cost of several million dollars. This will consist of substituting 20-in. pipe on 70 miles of the existing 195-mile system between Wink and El Paso, which now has two parallel 8-in. lines. The initial project will increase deliveries of crude to El Paso by 10,000 to 55,000 bbl a day.

Thereafter, Petersen said, Pasotex can quickly convert the remaining section to 20 in. to make 220,000 bbl a day available at El Paso.

"In the event of an emergency," he said, "it would be a relatively simple matter for Southern Pacific Pipe Lines, Inc., to change over to transportation of crude oil all the way to Los Angeles. The outstanding feature of this arrangement would be its flexibility to meet sudden emergencies.

"With crude available in large amounts at El Paso through the Pasotex line, it also would be relatively easy to lay another 20-in. line from the Texas border to Southern California. This could be done in 90 days, if necessary."

Plan 50-Mile Crude Oil Line in Alberta

A new 50-mile crude oil pipe line is proposed to link the Sundre and Westward Ho oil fields of west central Alberta with Calgary refineries. Cremona Pipelines Ltd. has applied to the Petroleum and Natural Gas Conservation Board for permission to build the line and lay a gathering system. Preliminary surveys have been made on the route of the proposed line.

Cremona is a subsidiary of the Oilwell Operators Ltd. group, consisting of Home Oil Company, Ltd., and Federated Petroleums, Ltd. interest, which control a substantial proportion of the indicated productive acreage in this Mississippian Foothills area. If the application is approved, objective would be to complete construction before the end of the summer.

New York State Natural Given Line Authorization

The Federal Power Commission has issued a certificate to New York State Natural Gas Corporation, of Pittsburgh, Pennsylvania, authorizing the construction and operation of approximately 21 miles of natural gas transmission line, paralleling a section of existing line, in Wyoming and Livingston counties, New York.

The new section of pipe will complete the looping of New York State Natural's existing line No. 14, which extends from a point in Potter County, Pennsylvania, to a connection with Rochester Gas and Electric Corporation near Caledonia, New York.

Texas Gas Has $20,000,000 Project On File With FPC

The Federal Power Commission has accepted for filing an application by Texas Gas Transmission Corporation, of Owensboro, Kentucky, requesting authority to construct a total of about 198 miles of natural gas transmission line and an additional 20,270 hp in compressor capacity along the route of its system in Louisiana, Arkansas, Mississippi, Tennessee, Kentucky and Indiana.

The project, estimated to cost a total of $19,969,000, would be used to make available an additional 35,000,000 cu ft of natural gas per day to Ohio Fuel Gas Company, of Columbus, Ohio, and a total of 73,598,000 cu ft daily to 36 other customers of Texas Gas.

Contracts Awarded for Pacific Northwest System

Construction contracts totaling $7,065,000, covering 509 miles of main line and lateral and 47 miles of gathering lines, have been awarded by Pacific Northwest Pipeline Corporation. Fish Northwest is designing and building the vast pipe line system from the San Juan Basin in New Mexico through Colorado, Utah, Wyoming, Idaho, Oregon, and Washington.

Contracts awarded cover the four main line sections extending from near Burley, Idaho, to the Columbia River at the Oregon-Washington border. This portion of the 1466-mile main line system will consist of 412 miles of 22-in. pipe. Also awarded were some 97 miles of 10¾-in and 16-in. lateral lines running to the Big Piney field and the Piceance Creek field, as well as the 47 miles of gathering system lines in these areas. The successful contractors on the work are as follows:

Sections 9 and 10, 214 miles of 22-in. between Burley, Idaho, and Payette, Idaho, at the Oregon-Washington border—H. B. Zachry Company, San Antonio, Texas.

Sections 11 and 12, 198 miles 22-in. between Payette, Idaho, and the Columbia River at the Oregon-Washington border—Fulghum Construction Company, Harrisburg, Pennsylvania.

Section 26 (Big Piney area) 54 miles 16-in. lateral and 31 miles gathering system line 2⅜-in. to 18-in from a point on the main line near Kemmerer, Wyoming, to the Big Piney field—A. J. Curtis Construction Company, Casper, Wyoming.

Section 27 (Piceance Creek area) 43 miles 10¾-in. lateral line and 16 miles gathering system lines 3½ in. to 10¾-in. from Rangely, Colorado, to the Piceance Creek field—R. H. Fulton and Company, Lubbock, Texas.

Cities Service Applies For New Gas Line

Cities Service Gas Company, of Oklahoma City, Oklahoma, has applied to the Federal Power Commission for authority to construct a total of about 238 miles of pipe line and a new 2700-hp compressor station on its transmission system in Kansas and Oklahoma.

The proposed construction, estimated to cost $8,422,000, is designed to increase the daily capacity of the company's system by approximately 50,000,000 cu ft in 1955 and 100,000,000 cu ft thereafter.

The project includes 93 miles of 26-in. pipe line extending from a point in Kay County, Oklahoma, to a point in Montgomery County, Kansas; a new 2700-hp compressor station in Woods County, Oklahoma, and about 145 miles of pipe in a gas gathering and transmission system in Woods County, Oklahoma, and Barber County, Kansas, connecting a new gas supply in Barber County with the proposed new compressor station.

Cities Service to Abandon Old Line, Build New

The Federal Power Commission has issued a certificate to Cities Service Gas Company of Oklahoma City, Oklahoma, authorizing it to abandon and remove approximately 41 miles of natural gas pipe line, and to construct about 39 miles of new line—generally as replacement facilities—in Newton, Lawrence, Lafayette, and Johnson counties, Missouri, and Johnson County, Kansas.

Trunkline Given Temporary Authority for Facilities

The Federal Power Commission has granted temporary authorization for Trunkline Gas Company, of Houston, Texas, to construct eight new compressor stations and 24 miles of pipe line on its natural gas transmission system in Texas, Louisiana, Mississippi, Tennessee, and Illinois.

The commission withheld authority for Trunkline to operate the new facilities pending determination of the proper allocation of the additional sales capacity that will become available upon completion of the construction. The commission said that its action in granting temporary authorization "is without prejudice to such disposition of the application for a certificate as the record may require." Total estimated cost of Trunkline's project is $17,686,000.

Pipe Line Planned For Montana Pool

Two Billings, Montana, men, D. J. Erkness and Arthur Hartwig, have announced plans for construction of a 100-mile pipe line from the Sumatra pool of Central Montana, to Billings. Oil is presently being trucked from this area to Billings refineries. Probable purchasers of the oil are reported to be Carter Oil Company, Continental Oil Company, and Farmers Union Oil Company, plants located in Billings.

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"I've seen coal tar pitch that'd been underground 75 years and still in good shape — was on the foundation of the old Grand Central Station in New York. Yessir, asphalt makes good roads and things where the sun gets to it — but underground it's best to use coal tar, otherwise you're trying to work against nature. You can bet your boots coal tar pitch is better'n asphalt to go on pipe.

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For Gas Transmission Lines This Year $725,000,000

The gas utility and pipe line industry spent $1,055,000,000 during 1954 on construction of new facilities, the American Gas Association reports. It is expected that in 1955 the industry's total construction will aggregate $1,385,000,000. This would make expenditures for new construction and plant expansion in the current year the second highest in the history of the gas industry, surpassed only by the total of $1,462,000,000 spent in 1951 for construction.

Transmission expenditures in 1954 aggregated $394,000,000 and are estimated at $725,000,000 in 1955. Two major pipe line projects are expected in 1955. The Pacific Northwest Pipeline Company is constructing a 2000-mile pipe line from the San Juan Basin field in New Mexico to major cities in Idaho, Oregon, and Washington. This line will cost an estimated $160,000,000. The second large project is the proposed 1200-mile, 30-in. American Louisiana Pipe Line Company undertaking. This line will extend from the fields of Louisiana to the Detroit Metropolitan area. The cost of this project will be about $130,000,000.

Construction of these lines and other smaller projects brought natural gas pipe line mileage up to approximately 420,000 miles at the end of 1954.

During the four years, 1955-1958, the gas industry expects new construction costs will equal about $4,315,000,000, somewhat under the record $4,933,000,000 spent on this work in the 1951-1954 historical period. The forecast includes totals of $1,205,000,000 for construction in 1956; $974,000,000 for new facilities in 1957, and $751,000,000 to be spent in 1958.

Committee Names Slate American Gas Officers

The general nominating committee of the American Gas Association has presented a list of leading executives from gas utility, pipe line, and manufacturer company members as its slate of general officers, directors, and section officers for submission at the AGA annual convention. Association officers and section chairmen will be elected for the 1955-56 association year and directors will be elected for two-year terms expiring in 1957.

Nominees will be voted upon by the membership at the 1955 annual convention in Los Angeles, October 17-19.

Offices to be filled are those of president, two vice presidents, treasurer, 15 directors, and 11 section chairmen and vice chairmen. General officers nominated are:

For president: Dean H. Mitchell, president, Northern Indiana Public Service Company, Hammond, Indiana.

For first vice president: C. H. Zachry, president, Southern Union Gas Company, Dallas, Texas.

For second vice president: A. W. Conover, president, Equitable Gas Company, Pittsburgh, Pennsylvania.

For treasurer: Vincent T. Miles, treasurer, Long Island Lighting Company, Mineola, New York

California Offshore Pipe Line Completed

A 10,500-ft pipe line system connecting offshore wells of Monterey Oil Company and The Texas Company with the mainland at Seal Beach, California, has been completed and is now in operation.

Oil from seven producing wells located on a man-made island is flowing through the pipe line to a separation center at the rate of 1500 bbl a day. Initially these wells were produced on a temporary basis for test, and the oil was transported ashore by barge. With installation of the pipe line they can now be produced continuously.

The main oil line from the island is 8 in. in diameter and has a capacity of 10,000 bbl per day. Three other lines, each 3 in. in diameter, also have been placed in service. One is used to deliver water to the island, another carries diesel oil, and the third is used in testing individual wells.

WITH THE PIPE LINE CONTRACTORS

● **J. P. Neill and Company, Dallas,** and **C. S. LeNoir and Company, Austin, Texas.** As joint venture are laying 77 miles of 36-in. gas line in Georgia and South Carolina for *Transcontinental Gas Pipe Line Corporation.*

● **Brown & Root, Inc., Houston, Texas.** Has 30-in. section of *American-Louisiana Gas Pipe Line* from Arkansas-Louisiana border to North Tepetate, Louisiana, and two 24-in. gathering lines near North Tepetate.

● **Hood Construction Company, Lynwood, California.** Has 112 miles of 8-in. and 35 miles of 12-in. for *Southern Pacific Pipe Lines* between Tucson and Hassayampa, Arizona.

● **Macco Corporation, Paramount, California.** Has 128 miles of 12-in for *Southern Pacific Pipe Lines* between Hassayampa, and Yuma, Arizona.

● **Conyes Construction Company, San Pablo, California.** Has 197 miles of 12-in. for *Southern Pacific Pipe Lines* between Yuma, Arizona, and Colton, California.

● **Fulghum Contracting Company, Harrisburg, Pennsylvania.** Has 198 miles of 22-in. between Payette, Idaho, and the Columbia River at the Oregon-Washington Border for *Pacific Northwest Pipe Line.*

● **Williams-Austin Company, 3322 Grant Building, Pittsburgh, Pennsylvania.** Has 31 miles of 26-in., three loops in Upshur, Braxton, and Randolph counties, West Virginia, for *Atlantic Seaboard Corporation.* Ed Peters general superintendent, L. A. Franks assistant superintendent, Ralph Gaddy spread superintendent.

● **C. P. Bartley and Son, Box 36, Tioga, North Dakota.** Has 20 miles of 2-in. through 8-in. gathering system for *Signal Oil and Gas Company.*

● **Baughman Contracting Company, Inc., R. D. 1, Box 569, Cumberland, Maryland.** Laying an undetermined amount of 24-in. through 16-in. gas lines in Maryland, Ohio, Pennsylvania, and West Virginia for *Cumberland and Allegheny Gas Company, Natural Gas Company of West Virginia,* and *Manufacturers Light and Heat Company.*

● **Somerville Construction Company, Ada, Michigan.** Has 22 miles of 16-in. for *Michigan Consolidated Gas Company,* from Sparta to Muskegon.

● **O. R. Burden Construction Corporation, 6702 East 21st, Tulsa, Oklahoma.** Has 31 miles of 30 and 36-in. in Louisiana for *Transcontinental Gas Pipe Line Corporation.* Also has 120 miles of 12 and 14-in. between Midland and Corsicana, Texas, on looping project for *Magnolia Pipe Line Company.* Also has 103 miles 12 and 16-in. for *Butte Pipe Line Company* between Hammond and Cabin Creek, Montana.

● **Mannix, Ltd., 332 7th Avenue West, Calgary, Alberta, Canada.** Has 100 miles of 3 through 10-in. gathering system for *Pembina Pipe Line Company.* George Hupp, manager; field office at Drayton Valley, Alberta.

● **Foster-Wheeler Corporation, 165 Broadway, New York 6, New York.** Has overall supervision of a 1920-mile NATO pipe line system in Europe.

● **Williams Pressure Service Company, 422 Commercial National Bank Building, Shreveport, Louisiana.** Has test on 200 miles of 8 through 26-in. for *Texas Gas Transmission* on looping program. Also has 84 miles of 36-in. line to test for Houston Contracting Company on *Transcontinental Gas Pipe Line* looping program. Also has 385 miles of 30-in. to test for *Texas Eastern Transmission* on line between Beaumont and Kosciusko, Mississippi.

● **Fulton-Banister, Ltd., 409 Northern Hardware Building, Edmonton, Alberta.** Has 106 miles and 16-in. between Edson, Alberta, and Valleyview, Alberta, for *Peace River Oil Pipe Line Company, Ltd.*

● **Sam Carline, Inc., Box 138, Berwick, Louisiana.** Has large amount of 3 and 4-in. underwater lines for *Shell Oil Company* in West Bay, Louisiana.

● **Hupp, Ltd., 332 West Seventh Avenue, Calgary, Alberta.** Has 400 miles of 4, 6, and 8-in. lines for *Pembina Pipe Line, Ltd.,* gathering system in the Pembina field of Alberta.

● **Majestic Contractors, Ltd., 408 Royal Trust Building, Edmonton, Alberta.** Has 226 miles of 10, 12, and 14-in., for *Saskatchewan Power Corporation* in Saskatoon and Saskatchewan.

● **Banister Construction, Ltd., 409 Northern Hardware Building, Edmonton, Alberta.** Has 53 miles of 12-in. distribution system for the city of Prince Albert, Canada.

● **Anderson Brothers Corporation, Box 8157, Houston, Texas.** Has 88 miles of 10 and 12-in. from Poplar to Glendive, Montana, for *Butte Pipe Line Company.*

● **Midwestern Constructors, Inc., 402 North Boulder, Tulsa, Oklahoma.** Has 53.5 miles of 36-in. in Alabama for *Transcontinental Gas Pipe Line Corporation.* Also has 95 miles of 22-in. between Lava Hot Springs, Idaho, and Burley, Idaho, for *Pacific Northwest Pipe Line Company.*

● **Panama-Williams Company, Melrose Building, Houston, Texas.** Has 36 miles of 30-in. and 31.4 miles of 36-in. in South Carolina and North Carolina for *Transcontinental Gas Pipe Line Corporation.* W. H. Shiflett, superintendent; Lloyd Evans, assistant superintendent; Hank Scherer, office manager.

● **Buchanan Pipe Line Construction Company, Birmingham, Alabama.** Has 80 miles of 6 and 8-in. for *South Georgia Natural Gas Company.*

● **B&M Construction Corporation, Oklahoma City, Oklahoma.** Has contract for construction of 475 miles of 8, 10, and 12-in. products line from Rota to Zaragoza, Spain, for *U. S. Navy* as part of joint venture with Merritt-Chapman & Scott Corp., New York, and Agroman Empresa Construction, Madrid. A. C. Montin, project manager, in care of Hilton Hotel, Madrid, Spain. Job started June 1, 1955. Also has 90 miles of 22-in. between Sage, Wyoming, and Lava Hot Springs, Idaho for *Pacific Northwest Pipe Line.*

● **Pipe Line Service Company, Seminole, Oklahoma.** Has 140 miles of 24-in. for *Transok Pipe Line Company* between Lindsay and Tulsa, Oklahoma.

● **Merritt-Chapman & Scott Corporation, 260 Madison Avenue, New York 16, New York.** Has 53 miles of 8 to 24-in. between Bombay and Butcher Island for *Bombay Port Trust, India.* Also joint venture with Benson and Montin and Agroman Empresa Construction for 475 miles of 8, 10, and 12-in. between Rota and Zaragoza, Spain, for *U. S. Navy.*

● **Engineering-Construction Company, 402 North Cheyenne, Tulsa, Oklahoma.** Has 150 miles, 6 to 10-in. gas line for *Southeast Alabama Gas District.* Two spreads: Gene Coulter, superintendent at Eufaula, Alabama, and Jim Williams, superintendent, Headland, Alabama.

● **Arey Construction Company, Box 1501 Pampa, Texas.** Has 100 miles 6-in. for *Shamrock Oil and Gas Company.* Amarillo to Lubbock, Texas. H. V. Gorman, superintendent.

● **Missouri Valley Dredging, 22 William Street, Omaha 8, Nebraska.** Has approximately 6400 ft ditch and backfill on Hudson River Crossing near Dobbs Ferry, New York for *Tennessee Gas Transmission.* Also has two 30-in. crossings, Sabine River near Deweyville, Texas, and Bayou Courtableau, Port Barre, Louisiana, for *Texas Eastern Transmission.*

● **Pipe Line Contracting and Drilling Company, P. O. Box 165, Lemoyne, Pennsylvania.** Has 46 miles of 26-in. in three loops in West Virginia and Maryland for *Atlantic Seaboard Gas Corporation.*

● **H. C. Price Company, Box 1111, Bartlesville, Oklahoma.** Has for *Tennessee Gas Transmission Company* approximately 18 miles of 24-in. connecting Harrison and Hebron Storage fields and 50 miles of mainline, 24-in. Also has 77 miles of 26-in. in western Kentucky and Tennessee in six main line loops, plus 77 miles of 16-in. in Kentucky and Indiana, 5 miles of 8-in. and 35 miles of 10-in. in Indiana for *Texas Gas Transmission Corporation.* Also has 134 miles of 30-in. for *Texas Eastern Transmission* between Mississippi River near New Roads, Louisana, and Clinton, Mississippi. Also has (with Houston Contracting Company) 783 miles of 30-in. between Detroit and Louisiana-Arkansas line for *American-Louisiana Pipe Line,* of which 400 miles will be built in 1955, 185 by Price and 215 by Houston.

● **H. L. Gentry Construction Company, Box 32, Perrysburg, Ohio.** Has 16 miles of 8, 12, and 16-in. gas lines for *Iroquois Gas Corporation* at Colden, New York.

● **R. H. Fulton & Company, Box 1526, Lubbock, Texas.** Has 55 miles of 30-in. steel water line for *City of Colorado Springs, Colorado*. Has 150 miles of 8-in. between Tucson, Arizona, and Lordsburg, New Mexico, for *Southern Pacific Pipe Lines*. Has 160 miles of 26-in. for *Pacific Northwest Pipe Line* between Moab and Jensen, Utah. Has 256 miles of 22-in. between Rock Springs and Laramie, Wyoming, for *Colorado Interstate Gas Company*. Also has 43 miles of 10-in. and 16 miles of 3 to 10-in. near Rangely, Colorado for *Pacific Northwest Pipe Line*.

● **Dutton-Williams Brothers, Ltd., Pacific Building, Calgary, Alberta.** Has 51 miles of 4 and 6-in. from Joffre and Clive fields to Stettler, Alberta, for *Canadian Gulf Pipe Line Company*.

● **River Construction Company, 6100 Camp Bowie Boulevard, Fort Worth, Texas.** Has 150 miles of 8-in. between El Paso, Texas, and Lordsburg, New Mexico, for *Southern Pacific Pipe Lines, Inc*. Also has 150 miles of 26-in. between Ignacio, Colorado, and Moab, Utah, in two spreads, for *Pacific Northwest Pipe Line Corporation*. Also has 57 miles of 6-in. between Enid and Ponca City, Oklahoma, for *Champlin Refining Company*.

● **Hallmac Construction Company, 2261 West Holcombe, Houston, Texas.** Has approximately 100 miles of 10-in. for *South Georgia Natural Gas Company*.

● **Cumberland Contracting Company, Monticello, Kentucky.** Has approximately 225 miles of 2 through 10-in. for *Southeast Alabama Gas District*.

● **Associated Pipe Line Contractors, Box 13216, Houston, Texas.** Has 63.5 miles of 36-in in Louisiana and Mississippi and 71 miles of 30-in. in Virginia and Maryland for *Transcontinental Gas Pipe Line Corporation*. Also has 77 miles of 26-in. between Jensen, Utah and Green River, Wyoming, for *Pacific Northwest Pipe Line*. Also has 227 miles of 16-in. for *Butte Pipe Line* between Guernsey, Wyoming, and the Montana line. Also 425 miles of 4, 6, and 8-in. products pipe line for Turkey, sponsored by NATO.

● **H. B. Zachry Company, Box 2570, San Antonio, Texas.** Has 67 miles of 30-in. for *Texas Eastern Transmission* between Clinton and Kosciusko, Mississippi. Also has 214 miles of 22-in. between Burley Idaho and Payette, Idaho for *Pacific Northwest Pipe Line*.

● **Sheehan Pipe Line Construction Company, 514 National Bank of Tulsa Building, Tulsa, Oklahoma.** Has 6600 ft of 16-in. river crossing on Red River near Ringling, Oklahoma, for *Sinclair Pipe Line Company*. Also has 49 miles of 8-in. between West Chester and Allentown, Pennsylvania, for *Keystone Pipe Line Company*. Also 75 miles of 8-in. reconditioning for *Buckeye Pipe Line Company* between Lima, Ohio, and Huntington, Indiana.

● **Williams Brothers, National Bank of Tulsa Building, Tulsa, Oklahoma.** Has 160 miles of 6-in. for *Bolivian government*, oil line. Has 115 miles of 30-in. between Toledo and Cleveland, Ohio, for *East Ohio Gas Company*. Has 72 miles of 30-in. in Virginia for *Transcontinental Gas Pipe Line Corporation*. Has 120 miles of 30-in., sections II and III, between Gillis, Louisiana, and the Mississippi River, for *Texas Eastern Transmission Corporation*.

● **Oklahoma Pipe Line Constructors, 6612 Harry Hines Boulevard, Box 13227, Dallas, Texas.** Has 113 miles of 24-in. between Honesdale and Covington, Pennsylvania, for *Tennessee Gas Transmission Company*. N. L. "Cajun" Arie and Gene Gohring, superintendents at Uniondale and Montrose, Pennsylvania.

● **Engineers Limited Pipe Line Company, 225 Bush Street, San Francisco, California.** Has 226 miles of 16-in. for *Butte Pipeline Company* from Fort Laramie, Wyoming, to Hammond, Montana.

● **Mid States Construction Company, Box 417, Mt. Vernon, Illinois.** Has 110 miles of 2 through 12-in. for *South Georgia Natural Gas Company*.

● **A. J. Curtis Construction Company, Box 2009, Casper, Wyoming.** Has 83 miles of 22-in. between Green River and Sage, Wyoming, for *Pacific Northwest Pipe Line Company*. Also has 54 miles of 16-in. lateral and 31 miles of 2 through 18-in. near Kemmerer, Wyoming, for *Pacific Northwest Pipe Line*.

● **Houston Contracting Company, 2707 Ferndale Place, Houston 6, Texas.** Has 84.8 miles of 36-in. (with H. C. Price Company) in Alabama and Georgia for *Transcontinental Gas Pipe Line Corporation*. Has 140 miles of 22-in. for *Colorado Interstate Gas Company* from Laramie, Wyoming, to Denver, Colorado. Also has 59 miles of 30-in. for *Texas Eastern Transmission* between De Quincy Louisiana, and Beaumont, Texas. Also has (with H. C. Price Company) 783 miles of 30-in. for *American-Louisiana Pipe Line* from Willow Run, Michigan, to Eudora, Arkansas. Some 400 miles to be built in 1955, 215 by Houston and 185 by Price.

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	Weight, coupled,[1] lb.	Volume of fluid displaced, gal.	Weight of 9.5 lb./gal. fluid displaced, lb.	Net weight of drill pipe, lb.	Weight, coupled,[1] lb.	Volume of fluid displaced, gal.	Weight of 9.5 lb./gal. fluid displaced, lb.	Net weight of drill pipe, lb.	Weight, coupled,[1] lb.	Volume of fluid displaced, gal.	Weight of 9.5 lb./gal. fluid displaced, lb.	Net weight of drill pipe, lb.
2,000	17,000	259.8	2,470	14,530	22,400	342.2	3,250	19,150	26,600	406.4	3,860	22,740
2,200	18,700	285.8	2,715	15,985	24,640	376.4	3,575	21,065	29,260	447.0	4,245	25,015
2,400	20,400	311.8	2,960	17,440	26,880	410.6	3,900	22,980	31,920	487.7	4,635	27,285
2,600	22,100	337.7	3,210	18,890	29,120	444.9	4,225	24,895	34,580	528.3	5,020	29,560
2,800	23,800	363.7	3,455	20,345	31,360	479.1	4,550	26,810	37,240	569.0	5,405	31,835
3,000	25,500	389.7	3,700	21,800	33,600	513.3	4,875	28,725	39,900	609.6	5,790	34,110
3,200	27,200	415.7	3,950	23,250	35,840	547.5	5,200	30,640	42,560	650.2	6,175	36,385
3,400	28,900	441.7	4,195	24,705	38,080	581.7	5,525	32,555	45,220	690.9	6,565	38,655
3,600	30,600	467.6	4,445	26,155	40,320	616.0	5,850	34,470	47,880	731.5	6,950	40,930
3,800	32,300	493.6	4,690	27,610	42,560	650.2	6,175	36,385	50,540	772.7	7,335	43,205
4,000	34,000	519.6	4,935	29,065	44,800	684.4	6,500	38,300	53,200	812.8	7,720	45,480
4,200	35,700	545.6	5,185	30,515	47,040	718.6	6,825	40,215	55,860	853.4	8,110	47,750
4,400	37,400	571.6	5,430	31,970	49,280	752.8	7,150	42,130	58,520	894.1	8,495	50,025
4,600	39,100	597.5	5,675	33,425	51,520	787.1	7,475	44,045	61,180	934.7	8,880	52,300
4,800	40,800	623.5	5,925	34,875	53,760	821.3	7,800	45,960	63,840	975.4	9,265	54,575
5,000	42,500	649.5	6,170	36,330	56,000	855.5	8,125	47,875	66,500	1016.0	9,650	56,850
5,200	44,200	675.5	6,415	37,785	58,240	889.7	8,450	49,790	69,160	1056.6	10,040	59,120
5,400	45,900	701.5	6,665	39,235	60,480	923.9	8,775	51,705	71,820	1097.3	10,425	61,395
5,600	47,600	727.4	6,910	40,690	62,720	958.2	9,105	53,615	74,480	1137.9	10,810	63,670
5,800	49,300	753.4	7,155	42,145	64,960	992.4	9,430	55,530	77,140	1178.6	11,195	65,945
6,000	51,000	779.4	7,405	43,595	67,200	1026.6	9,755	57,445	79,800	1219.2	11,580	68,220
6,200	52,700	805.4	7,650	45,050	69,440	1060.8	10,080	59,360	82,460	1259.8	11,970	70,490
6,400	54,400	831.4	7,900	46,500	71,680	1095.0	10,405	61,275	85,120	1300.5	12,355	72,765
6,600	56,100	857.3	8,145	47,955	73,920	1129.3	10,730	63,190	87,780	1341.1	12,740	75,040
6,800	57,800	883.3	8,390	49,410	76,160	1163.5	11,055	65,105	90,440	1381.8	13,125	77,315
7,000	59,500	909.3	8,640	50,860	78,400	1197.7	11,380	67,020	93,100	1422.4	13,515	79,585
7,200	61,200	935.3	8,885	52,315	80,640	1231.9	11,705	68,935	95,760	1463.0	13,900	81,860
7,400	62,900	961.3	9,130	53,770	82,880	1266.1	12,030	70,850	98,420	1503.7	14,285	84,135
7,600	64,600	987.2	9,380	55,220	85,120	1300.4	12,355	72,765	101,080	1544.3	14,670	86,410
7,800	66,300	1013.2	9,625	56,675	87,360	1334.6	12,680	74,680	103,740	1585.0	15,055	88,685
8,000	68,000	1039.2	9,870	58,130	89,600	1368.8	13,005	76,595	106,400	1625.6	15,445	90,955
8,200	69,700	1065.2	10,120	59,580	91,840	1403.0	13,330	78,510	109,060	1666.2	15,830	93,230
8,400	71,400	1091.2	10,365	61,035	94,080	1437.2	13,655	80,425	111,720	1706.9	16,215	95,505
8,600	73,100	1117.1	10,615	62,485	96,320	1471.5	13,980	82,340	114,380	1747.5	16,600	97,780
8,800	74,800	1143.1	10,860	63,940	98,560	1505.7	14,305	84,255	117,040	1788.2	16,990	100,050
9,000	76,500	1169.1	11,105	65,395	100,800	1539.9	14,630	86,170	119,700	1828.8	17,375	102,325
9,200	78,200	1195.1	11,355	66,845	103,040	1574.1	14,955	88,085	122,360	1869.4	17,760	104,600
9,400	79,900	1221.1	11,600	68,300	105,280	1608.3	15,280	90,000	125,020	1910.1	18,145	106,875
9,600	81,600	1247.0	11,845	69,755	107,520	1642.6	15,605	91,915	127,680	1950.7	18,530	109,150
9,800	83,300	1273.0	12,095	71,205	109,760	1676.8	15,930	93,830	130,340	1991.4	18,920	111,420
10,000	85,000	1299.0	12,340	72,660	112,000	1711.0	16,255	95,745	133,000	2032.0	19,305	113,695
10,200	86,700	1325.0	12,585	74,115	114,240	1745.2	16,580	97,660	135,660	2072.6	19,690	115,970
10,400	88,400	1351.0	12,835	75,565	116,480	1779.4	16,905	99,575	138,320	2113.3	20,075	118,245
10,600	90,100	1376.9	13,080	77,020	118,720	1813.7	17,230	101,490	140,980	2153.9	20,460	120,520
10,800	91,800	1402.9	13,330	78,470	120,960	1847.9	17,555	103,405	143,640	2194.6	20,850	122,790
11,000	93,500	1428.9	13,575	79,925	123,200	1882.1	17,880	105,320	146,300	2235.2	21,235	125,065
11,200	95,200	1454.9	13,820	81,380	125,440	1916.3	18,205	107,235	148,960	2275.8	21,620	127,340
11,400	96,900	1480.9	14,070	82,830	127,680	1950.5	18,530	109,150	151,620	2316.5	22,005	129,615
11,600	98,600	1506.8	14,315	84,285	129,920	1984.8	18,855	111,065	154,280	2357.1	22,395	131,885
11,800	100,300	1532.8	14,560	85,740	132,160	2019.0	19,180	112,980	156,940	2397.8	22,780	134,160
12,000	102,000	1558.8	14,810	87,190	134,400	2053.2	19,505	114,895	159,600	2438.4	23,165	136,435
12,200	103,700	1584.8	15,055	88,645	136,640	2087.4	19,830	116,810	162,260	2479.0	23,550	138,710
12,400	105,400	1610.8	15,300	90,100	138,880	2121.6	20,155	118,725	164,920	2519.7	23,935	140,985
12,600	107,100	1636.7	15,550	91,550	141,120	2155.9	20,480	120,640	167,580	2560.3	24,325	143,255
12,800	108,800	1662.7	15,795	93,005	143,360	2190.1	20,805	122,555	170,240	2601.0	24,710	145,530
13,000	110,500	1688.7	16,045	94,455	145,600	2224.3	21,130	124,470	172,900	2641.6	25,095	147,805

[1]If a regular tool joint is inserted every 90 ft. all values for 8.50-lb. drill pipe will be increased about 2.4 percent, for 11.20-lb. drill pipe about 1.6 percent, and for 13.30-lb. drill pipe about 1.2 percent.

To obtain more information on products advertised see page E-27

What is your Control Need?

. . . a starter for a fractional hp motor?

This small inexpensive control provides thermal overload protection. . . . Compact construction permits mounting where space is at a premium. Designed for use on ac single-phase power systems . . . up to 230 volts.

. . . a controller for a 2300 to 5000-volt motor?

Here is a control for motors up to 2500 horsepower. All components — contactors, meters, overload relays, auxiliary switches — are selected to meet the particular requirements of your application. Current-limiting fuses give split cycle short circuit protection.

. . . or other applications?

Specific applications, including those between the above-mentioned limits, are made from an extensive line of starters and control components. These standard units are factory assembled in infinite combinations to meet practically any requirement. For help on a particular application, call your Allis-Chalmers representative. His recommendations are backed by Allis-Chalmers engineering departments . . . by experience gained solving thousands of control problems . . . by complete research and testing facilities.

A-4721

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

Milwaukee 1, Wisconsin

SQUARES OF WHOLE NUMBERS*

	0	1	2	3	4	5	6	7	8	9
500	250,000	251,001	252,004	253,009	254,016	255,025	256,036	257,049	258,064	259,081
510	260,100	261,121	262,144	263,169	264,196	265,225	266,256	267,289	268,324	269,361
520	270,400	270,441	272,484	273,529	274,576	275,625	276,676	277,729	278,784	279,841
530	280,900	281,961	283,024	284,089	285,156	286,225	287,296	288,369	289,444	290,521
540	291,600	292,681	293,764	294,849	295,936	297,025	298,116	299,209	300,304	301,401
550	302,500	303,601	304,704	305,809	306,916	308,025	309,136	310,249	311,364	312,481
560	313,600	314,721	315,844	316,969	318,096	319,225	320,356	321,489	322,624	323,761
570	324,900	326,041	327,184	328,329	329,476	330,625	331,776	332,929	334,084	335,241
580	336,400	337,561	338,724	339,889	341,056	342,225	343,396	344,569	345,744	346,921
590	348,100	349,281	350,464	351,649	352,836	354,025	355,216	356,409	357,604	358,801
600	360,000	361,201	362,404	363,609	364,816	366,025	367,236	368,449	369,664	370,881
610	372,100	373,321	374,544	375,769	376,996	378,225	379,456	380,689	381,924	383,161
620	384,400	385,641	386,884	388,129	389,376	390,625	391,876	393,129	394,384	395,641
630	396,900	398,161	399,424	400,689	401,956	403,225	404,496	405,769	407,044	408,321
640	409,600	410,881	412,164	413,449	414,736	416,025	417,316	418,609	419,904	421,201
650	422,500	423,801	425,104	426,409	427,716	429,025	430,336	431,649	432,964	434,281
660	435,600	436,921	438,244	439,569	440,896	442,225	443,556	444,889	446,224	447,561
670	448,900	450,241	451,584	452,929	454,276	455,625	456,976	458,329	459,684	461,041
680	462,400	463,761	465,124	466,489	467,856	469,225	470,596	471,969	473,344	474,721
690	476,100	477,481	478,864	480,249	481,636	483,025	484,416	485,809	487,204	488,601
700	490,000	491,401	492,804	494,209	495,616	497,025	498,436	499,849	501,264	502,681
710	504,100	505,521	506,944	508,369	509,796	511,225	512,656	514,089	515,524	516,961
720	518,400	519,841	521,284	522,729	524,176	525,625	527,076	528,529	529,984	531,441
730	532,900	534,361	535,824	537,289	538,756	540,225	541,696	543,169	544,644	546,121
740	547,600	549,081	550,564	552,049	553,536	555,025	556,516	558,009	559,504	561,001
750	562,500	564,001	565,504	567,009	568,516	570,025	571,536	573,049	574,564	576,081
760	577,600	579,121	580,644	582,169	583,696	585,225	586,756	588,289	589,824	591,361
770	592,900	594,441	595,984	597,529	599,076	600,625	602,176	303,729	605,284	606,841
780	608,400	609,961	611,524	613,089	614,656	616,225	617,796	619,369	620,944	622,521
790	624,100	625,681	627,264	628,849	630,436	632,025	633,616	635,209	636,804	638,401
800	640,000	641,601	643,204	644,809	646,416	648,025	659,636	651,249	652,864	654,481
810	656,100	657,721	659,344	660,969	662,596	664,225	665,856	667,489	669,124	670,761
820	672,400	674,041	675,684	677,329	678,976	680,625	682,276	683,929	685,584	687,241
830	688,900	690,561	692,224	693,889	695,556	697,225	698,896	700,569	702,244	703,921
840	705,600	707,281	708,964	710,649	712,336	714,025	715,716	717,409	719,104	720,801
850	722,500	724,201	725,904	727,609	729,316	731,025	732,736	734,449	736,164	737,881
860	739,600	741,321	743,044	744,769	746,496	748,225	749,956	751,689	753,424	755,161
870	756,900	758,641	760,384	762,129	763,876	765,625	767,376	769,129	770,884	772,641
880	774,400	776,161	777,924	779,689	781,456	783,225	784,996	786,769	788,544	790,321
890	792,100	793,881	795,664	797,449	799,236	801,025	802,816	804,609	806,404	808,201
900	810,000	811,801	813,604	815,409	817,216	819,025	820,836	822,649	824,464	826,281
910	828,100	829,921	831,744	833,569	835,396	837,225	839,056	840,889	842,724	844,561
920	846,400	848,241	850,084	851,929	853,776	855,625	857,476	859,329	861,184	863,041
930	864,900	866,761	868,624	870,489	872,356	874,225	876,096	877,969	879,844	881,721
940	883,600	885,481	887,364	889,249	891,136	893,025	894,916	896,809	898,704	900,601
950	902,500	904,401	906,304	908,209	910,116	912,025	913,936	915,849	917,764	919,681
960	921,600	923,521	925,444	927,369	929,296	931,225	933,156	935,089	937,024	938,961
970	940,900	912,841	944,784	946,729	948,676	950,625	952,576	954,529	956,484	958,441
980	960,400	962,361	964,324	966,289	968 256	970,225	972,196	974,169	976,144	978,121
990	980,100	982,081	984,064	986,049	988,036	990,025	992,016	994,009	996,004	998,001

*See footnote of table No. P 061.001.1.

RUSH SERVICE IS STANDARD PRACTICE IN FILLING ORDERS FOR GASO PARTS

Here Is Why It Pays To

GET GENUINE GASO PARTS

Our reputation is built on pumps that continue to deliver top performance long after ordinary pumps have been scrapped.

What's back of this record? Design principles that call for fewer parts, made *extra strong.*

By their nature such principles call for extraordinary care in the design and construction of parts. *Every detail of every Gaso part is precision made to specifications developed through years of experiment and research.*

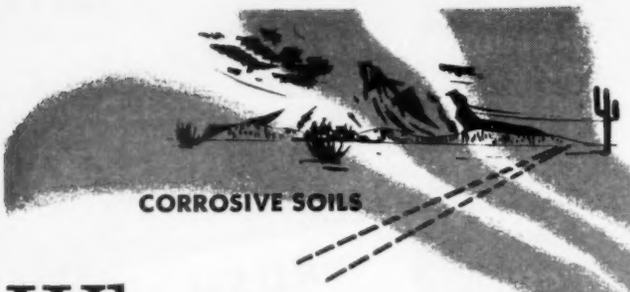
Only in genuine Gaso parts do you get the benefits of Gaso experience and standards. Why be satisfied with less?

Gaso parts are easy to get. You will find stocks both at Tulsa headquarters and at each of the distributors listed below.

GASO PUMP & BURNER MFG. CO. TULSA, OKLAHOMA
EXPORT OFFICE 149 Broadway, New York

LUFKIN MACHINE CO., Ltd., Edmonton, Alberta
W. L. SOMNER COMPANY, Shreveport, Louisiana
New Orleans, Louisiana • Odessa, Texas
Tinsley, Mississippi • Brookhaven, Mississippi
POWER PUMPS, INC., Long Beach, California
PEDDLERS, INC., Houston, Texas
NORTEX ENGINE & EQUIPMENT CO., Wichita Falls, Texas
LUFKIN FOUNDRY & MACHINE CO., Casper, Wyoming

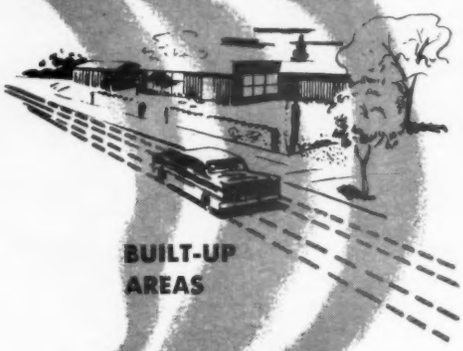
GASO PUMPS
for every oil industry need



CORROSIVE SOILS

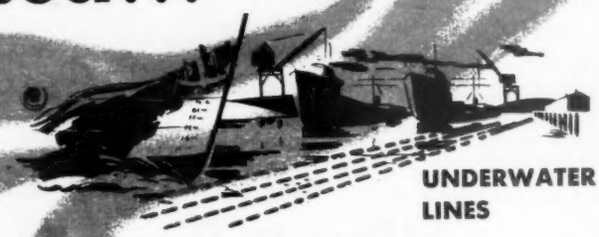
Soils of resistivities under about 2,000 ohm-cm, or soils of widely varying resistivities averaging even 5,000 ohm-cm or more, are usually quite corrosive. For such soils Somastic® Pipe Coating is the ideal solution. To avoid the expense of frequent changes in pipe treating equipment and crews on long lines, Somastic Pipe Coating should be used in sections of perhaps five to ten miles minimum length through such soils, even though intermediate stretches were of higher resistivity.

Where leakage cannot be tolerated...



BUILT-UP AREAS

Wherever pipe lines traverse city streets and subdivisions or valuable agricultural property, or lands that may soon be converted to such use, Somastic Pipe Coating is recommended. This added precaution is a good investment against the cost and public ill will that would result from a leak, even though soil studies may not indicate that severe corrosion should be anticipated. A further factor in such locations is that supplementary cathodic protection may not be feasible on poor coating because of the difficulty of obtaining suitable anode locations.



UNDERWATER LINES

Somastic Pipe Coating has long been the standard for swamp construction, river and harbor crossings, and coated submarine lines. Experience indicates that submarine lines and river crossings can be installed when Somastic Pipe Coating is used without the expensive handling precautions normally required for other coatings. Examples of such use can be supplied including submarine lines in the Persian Gulf, in Lake Maracaibo and in the Pacific.

ROUGH HANDLING

Although Somastic Pipe Coating can be damaged by unusually rough handling, it is true that it can be installed with a minimum of damage under conditions of mountainous terrain where prewrapped coatings would be damaged in handling and where over-the-trench machines cannot satisfactorily negotiate. Somastic Pipe Coating is usually the best choice when such construction problems are encountered.

POLLUTION DANGERS

Pipe lines are occasionally run through watersheds or river valleys where it is essential that every precaution be taken to prevent leaks. Such locations are an excellent application of Somastic Pipe Coating both because of the protection the coating affords and the evidence given to public authorities and others that the best possible pipe protection is being used.

you'll save money with SOMASTIC® coated pipe lines

SOMASTIC PIPE COATING is available in a number of formulations. Each is an asphalt-mastic designed for continuous, uniform, seamless, impermeable protection.

SOMASTIC PIPE COATING is *thick*. There are fewer pits under thick coatings. It is *seamless*. There are no holidays because of overlapping layers or bubbles. It is *reinforced*. The reinforcement is permanent and uniform. It is *rigid yet elastic* . . . withstands depression over long periods, absorbs pipe movement and changes in pipe line temperature. *Proved* under adverse soil conditions for more than 24 years. *That's why Somastic Pipe Coating will save you money wherever leakage cannot be tolerated!*

PIPE LININGS, Inc.

Specializing in Pipe Protection Problems · Interior Cement Mortar Lining · Somastic® Exterior Pipe Protection · Pipe Wrapping · Centrifugal Spinning of Cement Mortar Linings In Plant · Pipe Reclamation

Write for full information... **today!**

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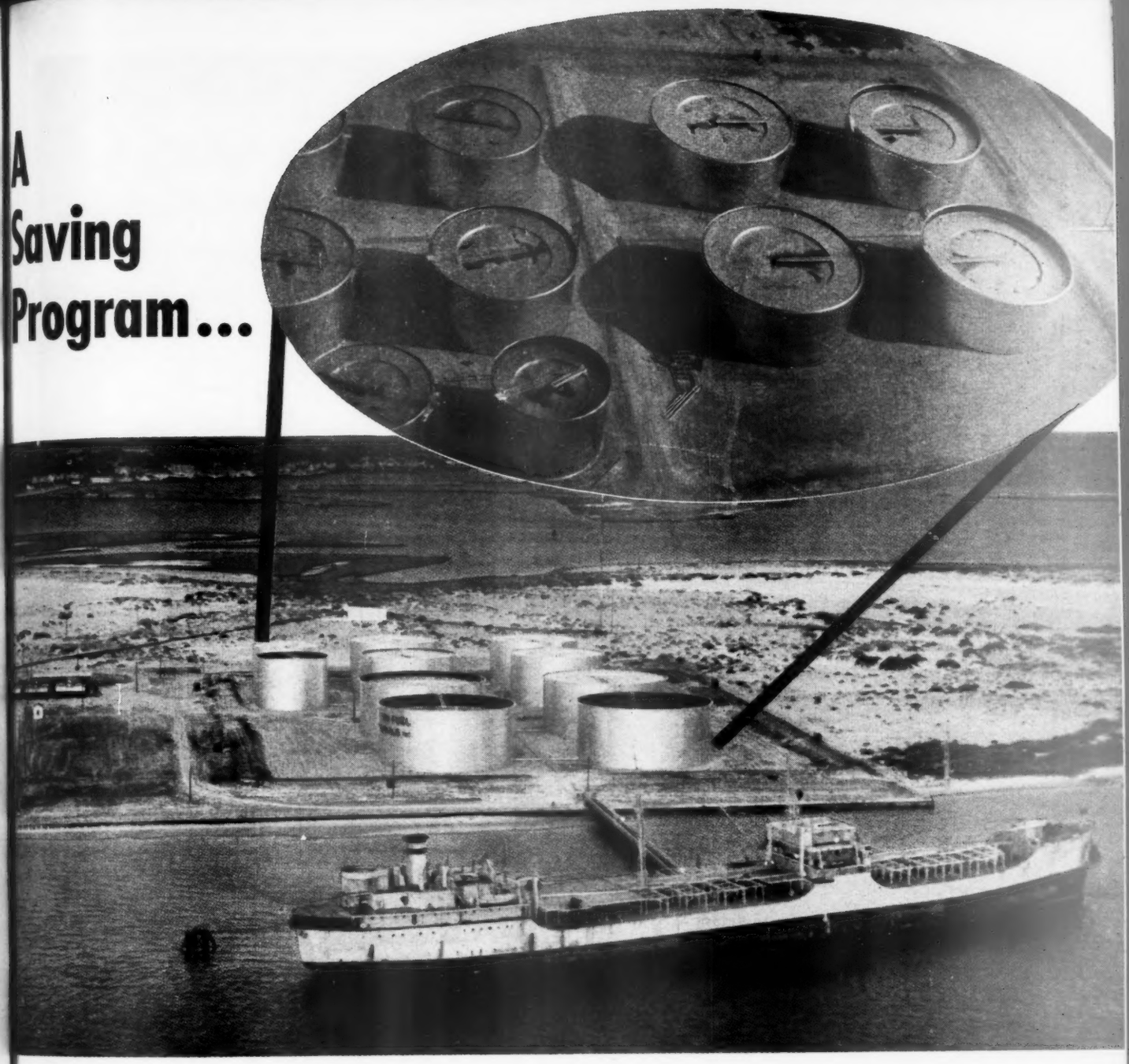
P. O. Box 457, Wilmington, California
Phone NEvada 6-1771 · Rail Address: Watson, California

To obtain more information on products advertised see page E-27

A Saving Program...



for a Fuel Terminal

When crude oil or motor gasoline is stored, it is necessary to take steps to prevent evaporation losses. Horton® Floating Roofs, Double-Deck, Pontoon and Pan, are designed and built for installation in flat-bottom oil storage tanks to reduce evaporation loss, decrease corrosion and eliminate fire hazards.

Aviation Fuel Terminals, Inc., at Beaufort, N. C. has ten tanks, a total of 600,000 bbls. of tankage, all equipped with Horton Pontoon Floating Roofs. Thus equipped, a real vapor saving program is constantly in effect at this fuel terminal.

When planning storage for volatile hydrocarbons, write our nearest office for information, estimates or quotations.

CBI

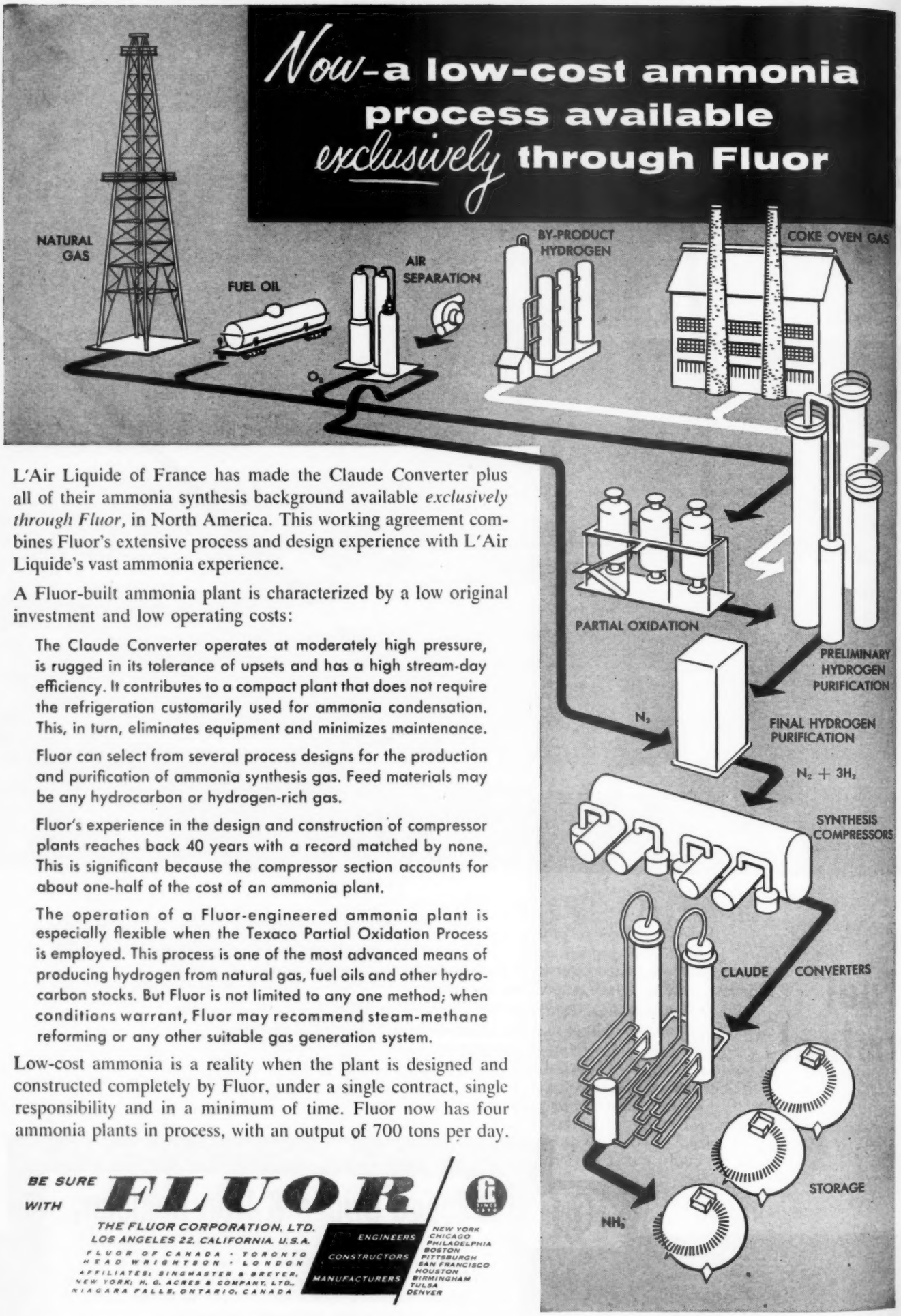
Chicago Bridge & Iron Company

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston
Los Angeles • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • Tulsa

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

REPRESENTATIVES AND LICENSEES:
Brazil • Canada • England • France • Italy • Netherlands • Scotland • Venezuela

XUM



L'Air Liquide of France has made the Claude Converter plus all of their ammonia synthesis background available *exclusively through Fluor*, in North America. This working agreement combines Fluor's extensive process and design experience with L'Air Liquide's vast ammonia experience.

A Fluor-built ammonia plant is characterized by a low original investment and low operating costs:

The Claude Converter operates at moderately high pressure, is rugged in its tolerance of upsets and has a high stream-day efficiency. It contributes to a compact plant that does not require the refrigeration customarily used for ammonia condensation. This, in turn, eliminates equipment and minimizes maintenance.

Fluor can select from several process designs for the production and purification of ammonia synthesis gas. Feed materials may be any hydrocarbon or hydrogen-rich gas.

Fluor's experience in the design and construction of compressor plants reaches back 40 years with a record matched by none. This is significant because the compressor section accounts for about one-half of the cost of an ammonia plant.

The operation of a Fluor-engineered ammonia plant is especially flexible when the Texaco Partial Oxidation Process is employed. This process is one of the most advanced means of producing hydrogen from natural gas, fuel oils and other hydrocarbon stocks. But Fluor is not limited to any one method; when conditions warrant, Fluor may recommend steam-methane reforming or any other suitable gas generation system.

Low-cost ammonia is a reality when the plant is designed and constructed completely by Fluor, under a single contract, single responsibility and in a minimum of time. Fluor now has four ammonia plants in process, with an output of 700 tons per day.

BE SURE WITH **FLUOR**

THE FLUOR CORPORATION, LTD.
LOS ANGELES 22, CALIFORNIA, U.S.A.
FLUOR OF CANADA · TORONTO
HEAD WRIGHTSON · LONDON
AFFILIATES: SINGMASTER & BREYER, NEW YORK; H. G. ACRES & COMPANY, LTD., NIAGARA FALLS, ONTARIO, CANADA

ENGINEERS
CONSTRUCTORS
MANUFACTURERS

NEW YORK
CHICAGO
PHILADELPHIA
BOSTON
PITTSBURGH
SAN FRANCISCO
HOUSTON
BIRMINGHAM
TULSA
DENVER

To obtain more information on products advertised see page E-27

Examine this new OIC valve model for 5 minutes. See how its unusual design features can lower your valve and maintenance costs.

It's an exact 2″ model of the newly designed OIC cast steel, lubricated plug valve. On test, its 6″ big brother endured 3000 full openings and closings at 425 p.s.i. pressure on solvent. It remained pressure tight, operable at low torque, and showed no sign of galling or seizing. You'll understand why, when you study the model.

See how its exclusive gland liner retains plug adjustment longer. Examine the valve's multiple seals. Operate it. Look at the design of its 4 plug grooves and see how more efficient lubricant distribution preserves the valve's primary seal. Its many life-extending features are all in the model.

Every OIC salesman has one. When he calls, ask to see it. Analyze its values. You'll be handling a model of the most modern lubricated plug valve known.

For complete advance information and specifications on the OIC lubricated plug valve line, write for Bulletin 1003.

OIC
FOUNDED 1883

THE OHIO INJECTOR COMPANY • WADSWORTH, OHIO

VALVES

FORGED & CAST STEEL, LUBRICATED PLUG, BRONZE & IRON VALVES

P-506

Here's what's happening in . . .

Gas Dehydration Today

A Four-Part Forum Discussion . . . .

- **Paper "Gas Dehydration . . . an Important Function of Low-Temperature Separation," C. K. Gravis, The Atlantic Refining Company, Dallas, Texas.**
- **Operator's Comments . . . Woodrow W. Mize, El Paso Natural Gas Company, Farmington, New Mexico.**
- **Manufacturer's Comments . . . A. W. Francis, National Tank Company, Tulsa, Oklahoma.**
- **Questions and Answers.**

Gas Dehydration . . . An Important Function of Low Temperature Separation

IT is difficult to separate the dehydration ability of low-temperature separation from other functions of the process. Low-temperature equipment is not used primarily for dehydration purposes, but the dehydration effect available is an important consideration in its application. A great deal has been learned about low-temperature separation processes, their application, and the economics involved. Much more is yet to be learned.

The first low-temperature separation unit entered the market in competition with conventional separation methods only a few years ago. Since then, there has been a ready acceptance of this type equipment for handling gas condensate production.

Information and criteria presented here were accumulated and developed from experience and data obtained in the application of 24 low-temperature separation (LTS) units and 6 cold-feed stabilizers. The LTS units range in capacity from 2,500,000 cu ft per day to 60,000,000 cu ft per day. Stabilizers range in capacity from 100 to 2000 bbl per day. These installations were made from September, 1950, to the present time. Smallest of the LTS units (2,500,000 cu ft per day capacity) is an abbreviated mechanical LTS unit taking production from a single well and using three-stage separation. Largest installation (60,000,000 cu ft per day capacity) is a glycol injection unit taking production from 28 wells and using a 2000 bbl per day condensate stabilizer. The abbreviated-type mechanical LTS unit shown schematically in Fig. 1 is a cold separator with a choke at the inlet and a means for melting hydrates in the bottom. Fig. 2 is a schematic flow diagram of a full mechanical-type LTS unit. It consists of a cold separator similar to the abbreviated type, but in addition includes a free water knockout and regenerative heat exchanger with appropriate temperature controls. The knockout removes free water or total liquids from the well stream. The heat exchanger and temperature controls will allow operation with a separator temperature of about 10 F lower than in the abbreviated unit. Although not

Highlight of the Tenth Annual Short Course on Gas Technology sponsored by the Division of Engineering, Texas College of Arts and Industries, Kingsville, Texas, June 1-3, 1955, was an open forum on gas dehydration. The original discussion was based on an API paper, "Practical Application of Low-Temperature Separation and Stabilization" by C. K. Gravis, T. O. Davis, and R. E. Fields, The Atlantic Refining Company, Dallas, Texas. Comments by an operator and an equipment manufacturer as well as questions and answers were recorded and transcribed. The complete package is presented here as a service to the readers of THE PETROLEUM ENGINEER.—THE EDITORS.

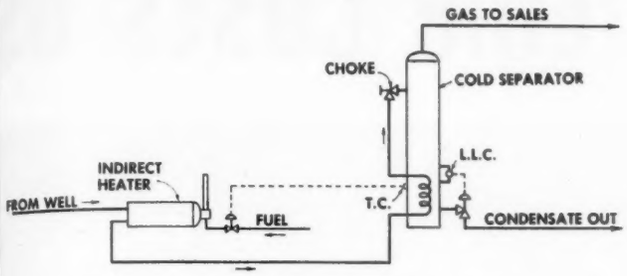


FIG. 1. Schematic flow diagram of abbreviated mechanical type LTS unit.

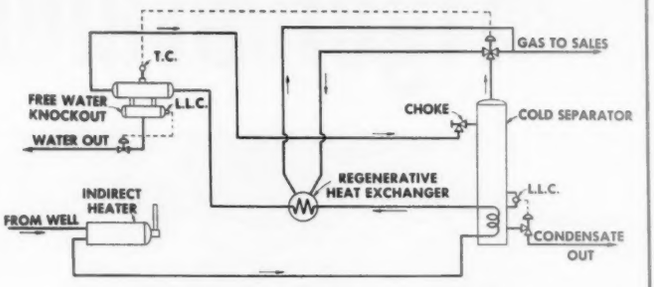


FIG. 2. Schematic flow diagram of full mechanical type LTS unit.

shown, a second stage of separation is considered advisable with either type of mechanical LTS unit.

The glycol-injection type LTS unit is shown schematically in Fig. 3. It consists of a glycol-oil separator, indirect heater, glycol regenerator, and glycol pumps in addition to equipment and controls of the full mechanical type. Use of glycol and extra equipment for handling glycol permits the unit to operate with separator temperatures from 30 to 50 F lower than mechanical units operating under identical flowing conditions.

It is advisable to base application of the LTS or stabilization process on actual conditions of each specific case. Several important items to be considered are: (1) Gas rate, (2) flowing well-stream pressure at this rate, (3) reservoir life, (4) operating separation temperature, (5) delivery pressure, (6) dehydration requirements, (7) flowing well-stream pressure, (8) oil-gas ratio, and (9) well-stream composition.

Application of the LTS process is justified in most every case involving those installations described earlier by increased recovery due to lower separation temperatures. When possible, increased recovery is determined by flash calculations. For preliminary investigations and when time does not allow sampling and flash calculations, a "rule of thumb" estimate is applied as follows: ".05 bbl of additional condensate can be recovered per million cubic feet for each degree F that the separator temperature is lowered below that of normal temperature separation. This rule of thumb has proved to be a valuable aid in that it represents approximately the average increased recovery due to low-temperature separation without stabilization of the many compositions investigated in these applications. Increased recovery can range from ½ to 4 bbl per million, depending upon the gas-oil ratio and gas composition. Recovery by stabilization must be calculated in each case for accuracy.

Table 1 indicates the approximate values for six of the most important application conditions for the various types of LTS units. Values shown for the first condition of initial flowing pressure are intended to represent the minimum for the proper application of all three LTS types illustrated.

TABLE 1. Approximate application conditions for the various types of LTS.

Conditions	Abbreviated type LTS	Full mechanical type LTS	Glycol injection type LTS
(1) Initial flowing press. at rate.....	2500 psi	2500 psi	1700 psi
(2) Average gas rate....	2 MM SCFPD or less	2 MM SCFPD or more	1.5 MM SCFPD up
(3) Production life.....	5 years or less	10 years	10 years
(4) Separation temp., below conventional separation temp...	35-40 F	45-50 F	40-50 F
(5) Delivery pressure...	1000 psi	1000 psi	1000 psi
(6) Dehydration effect or dew point depression.....	10 F	10 F	30 F

The average gas rate represents a possible range of rates up to the maximum for abbreviated mechanical LTS, but represents the minimum rate for proper justification of full mechanical and glycol LTS. This also holds true for the life of production, the third condition shown. Production or reservoir life noted in the table is based on an average or normally declining pressure reservoir. It is important to note that the economics of any LTS application may be affected greatly by the rate of decline in flowing pressure, regardless of how high the initial pressure may be.

Values listed for the fourth condition represent that separator temperature reduction available with the equipment type for the initial flowing pressure and delivery pressure shown in the chart. The 1000 psi delivery pressure for condition five was selected as being the most normal and representative case.

The dehydration effect or dew-point depression shown in the chart as condition six represents the amount generally available with the equipment type for the separator temperature reduction shown in the table. This gas dew-point depression is due to action of hydrates formed in mechanical-type LTS units. The dew-point depression in glycol LTS units is due to the hygroscopic effect of injected glycol.

Economic justification or installation payout varies from company to company. As a matter of clarification, an equipment payout period of 2 years, undiscounted and considering dehydration, was used in arriving at the conditions shown on this chart.

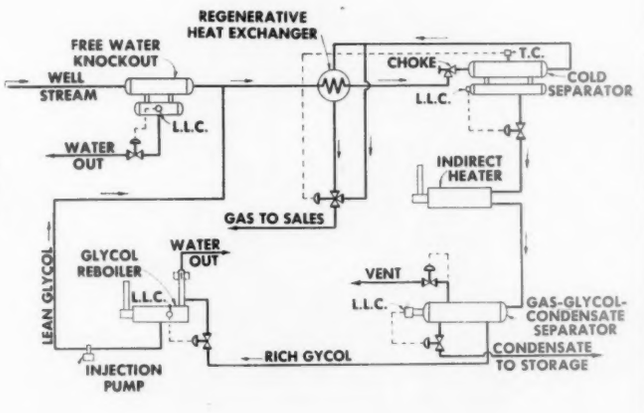
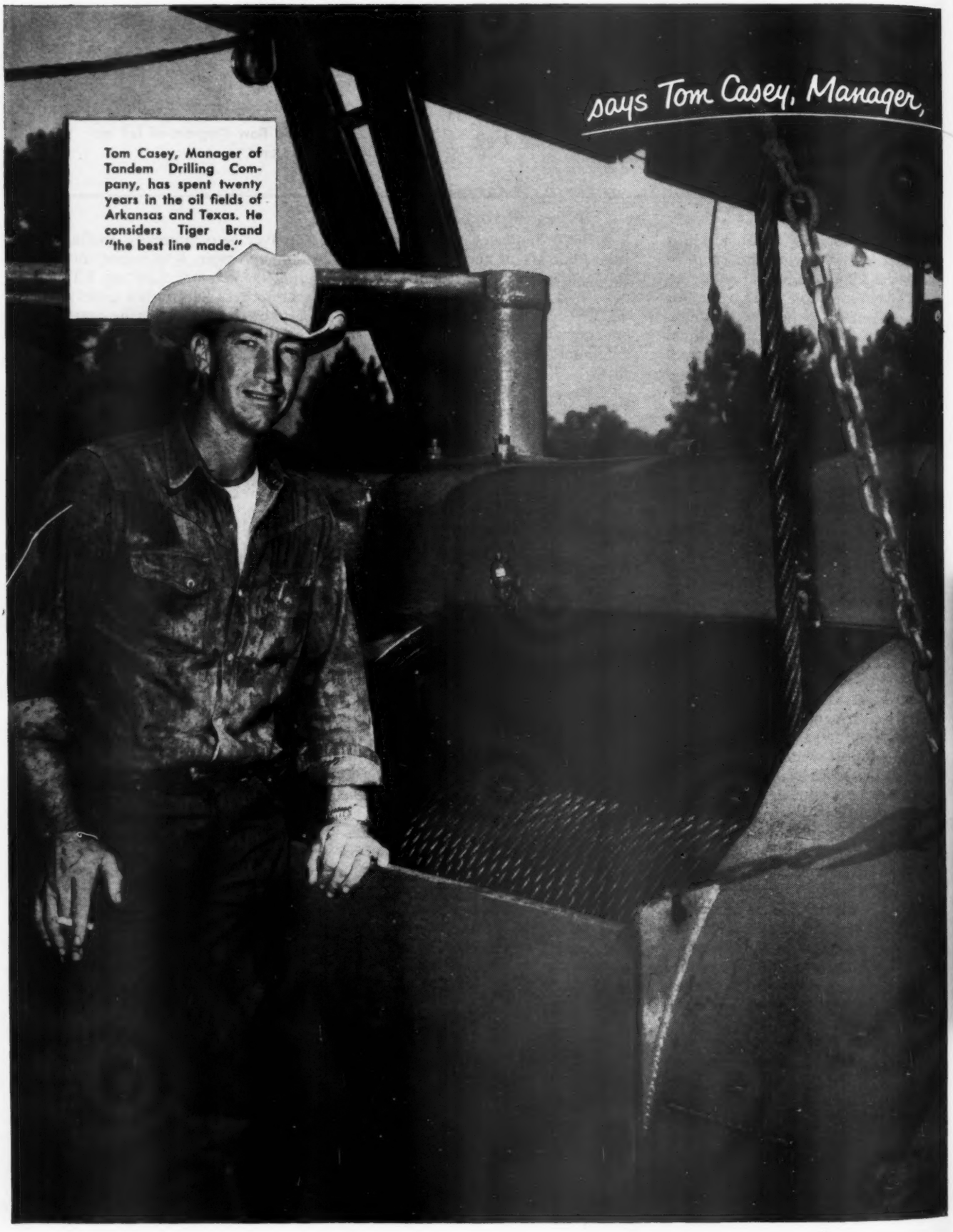


FIG. 3. Schematic flow diagram of glycol-injection type LTS unit.

"Tiger Brand Line costs us


says Tom Casey, Manager,
Tom Casey, Manager of Tandem Drilling Company, has spent twenty years in the oil fields of Arkansas and Texas. He considers Tiger Brand "the best line made."

only 11.9¢ per ton mile

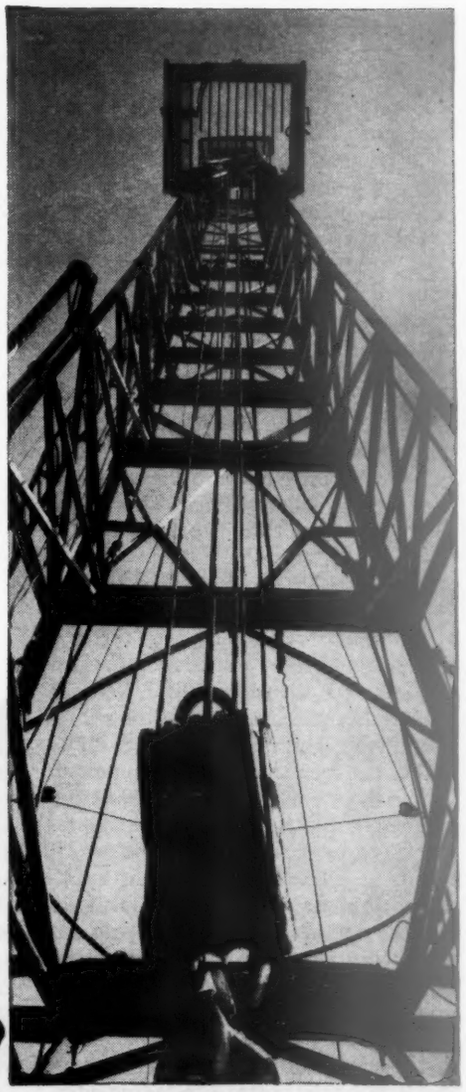
in Arkansas' East Schuler Field"

Tandem Drilling Company, Camden, Arkansas

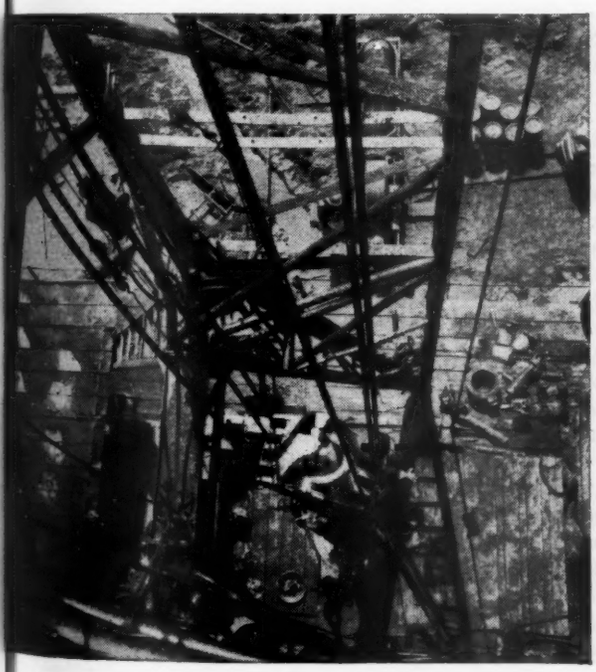
53,550 feet of hole from a 1450-foot Tiger Brand Rotary Drilling Line—the equivalent of about *nine* average wells. Drilled at an average rope cost of less than 12¢ a ton-mile. Through sand, shale, limestone, sweet and sour gas, condensate, crude oil, salt water.

"We couldn't ask for better service," says Tom Casey. "We tried two competitive lines. But each one lasted only a third as long as this Tiger Brand Line. Now we use Tiger Brand exclusively."

If you want long lasting lines, *low cost* lines, do like Tandem Drilling Company—use Tiger Brand.



This rig is going 24 hours a day. About every 1,000 ton miles the drilling line is cut-off to increase rope life. Tiger Brand is used for derrick, jerk, and tong lines, as well as drilling line.



Tandem Drilling Company needs a line that can take a maximum stress of 120,000 pounds and give them a safety factor of 5 to 1, so this driller uses 1⅛" Tiger Brand *Excellay* Line with wire rope core.

SEE THE UNITED STATES STEEL HOUR. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL
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GENERAL OFFICES: CLEVELAND, OHIO
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS AMERICAN TIGER BRAND WIRE ROPE

Excellay Preformed

USS

UNITED STATES STEEL

Abbreviated Mechanical LTS

This type has a much lower initial cost than other LTS types. The application of this type of LTS is particularly attractive to gas-condensate wells having low rates and short production lives along with a relatively high initial flowing pressure. Due to the nature of reservoirs usually attendant with this type of application, increased condensate recovery over conventional separation starts out at a maximum since the separator operates coldest in the early life of operation. Recovery will decrease as the separator temperature increases with the natural decrease in flowing pressure of the well, until the reservoir is depleted down to delivery pressure.

For the proper economic justification of abbreviated mechanical LTS units, the increased cost of the unit must be compared with the average predicted increased recovery for the required payout period or for the life of the reservoir down to delivery pressure. Due to the dehydration effect, this application possibly can be justified for the prevention of accumulated hydrates in delivery lines. This might assure production during winter months.

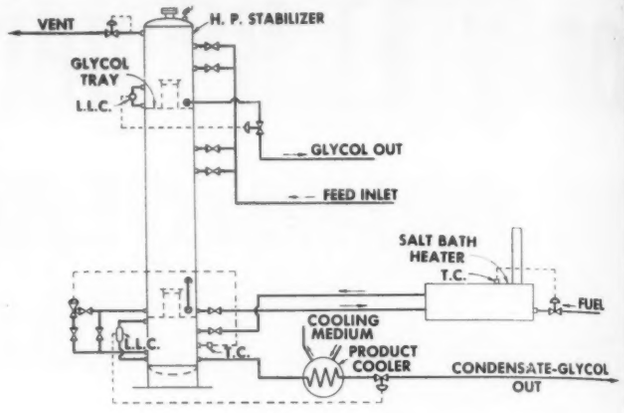

FIG. 4. Schematic diagram of high-pressure stabilizer.

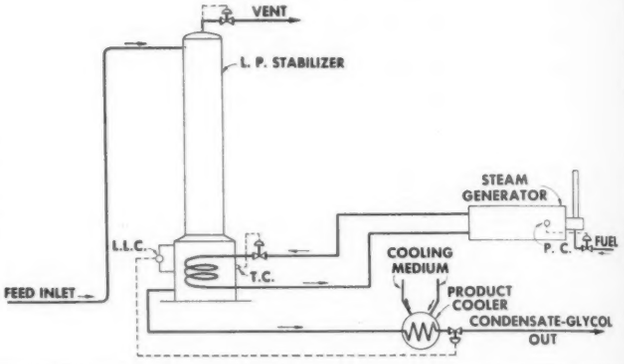

FIG. 5. Schematic diagram of low-pressure stabilizer.

Full Mechanical LTS

Minimum requirements for the proper application and economic justification of full mechanical LTS units must be better than those for the abbreviated type. This is due to higher initial cost of full mechanical-type equipment.

This type unit can do a credible job of dehydrating if separator temperatures are kept at 40 F or below. It would be difficult to justify the application of the full mechanical LTS process on the basis of satisfying gas sales contract dehydration specifications alone. This would be possible, however, if the well flowing pressures are constantly high through the life of the reservoir, or if the interest savings in deferring the costs of installing additional dehydration equipment are large.

Glycol Injection LTS

Economic justification and application of glycol-injection type LTS units can be diversified. This process can be applied easily and successfully to one or more wells in a system at different flowing pressures. Since the advent and development of the glycol LTS process, a single case is yet to be found in which the installation of full mechanical LTS was justified that the installation of glycol injection LTS with its additional cost could not also be justified.

Use of glycol LTS on the basis of increasing recovery requires that the separation conditions be at the optimum value available for each specific case. Separation temperature is of prime importance. Within the limits of the installations made, no instance has been found wherein recovery could not be increased by decreasing separator temperatures. Unless flash calculations indicate a different trend for some future composition, glycol LTS installations will be designed to give the minimum possible separation temperatures. We do not design for temperatures lower than —20 F, since that temperature is the lower allowable code limit on normal vessel and piping materials.

Glycol consumption in the glycol LTS unit is one of the most important keys to the success of the application. Major losses occur due to mechanical leakage or due to glycol-condensate emulsion conditions in the unit. Normal glycol consumption generally ranges between 1 and 2 gal per 100 bbl of condensate in a properly constructed and operated glycol LTS unit.

Glycol LTS does an excellent job of dehydration. When properly designed, the glycol LTS unit can effectively dehydrate gas to normal contract specifications until flowing pressures decline to within 500 to 600 psi of delivery pressure. Then, the addition of more equipment to accomplish dehydration is required. Glycol LTS has an economic advantage over other types of LTS due to longer deferment of additional dehydration equipment. In this way, dehydration is used as another means to pay out the additional cost of glycol LTS equipment.

The Stabilization Process

The economic criteria for application of the stabilization process have been developed from the installation and operation of two types of cold-feed stabilizers — the low-pressure type and the high-pressure type. Both of these types have been installed in conjunction with glycol LTS units. Fig. 4 shows a diagram of the high-pressure type stabilizer. This unit requires a salt bath heater to furnish the higher bottom temperature required. Twin salt bath heaters were used to furnish bottom heating. Fig. 5 is a schematic diagram of a low-pressure type stabilizer. This unit uses a 15 lb working pressure steam generator and a bottom heating coil that will satisfactorily produce required bottom temperature.

Since increased stock tank recovery is the usual basis for justifying a stabilizer installation, a market outlet should be established for as high a saleable Reid vapor pressure product as possible. Economics of the stabilizer installation will fall along the same lines as the companion LTS unit. Increased recovery due to stabilization and type of stabilization equipment installed depends upon the amount of gas and condensate being processed by the LTS unit and the separation temperature.

Increased recovery due to stabiliza-

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tion is difficult to approximate. For accuracy, it must be determined by test or flash calculations based on the composition of the well stream. Additional justification is a comparison of the increased recovery due to stabilization with the installation cost. In planning cold-feed stabilizer applications in conjunction with LTS units, only one case has been found in which the cost of the installation could not be justified. Calculations showed that stabilization in this case would give only a negligible increase in recovery over glycol LTS with 3-stage separation. This was due to lack of sufficient intermediate hydrocarbons in the well stream.

Consider Each Case

Always consider the relative merits of each type of LTS on an increased recovery, dehydration, initial cost, and operating cost basis to decide which type to install. Use of abbreviated mechanical LTS as well as full mechanical LTS should always be considered if only to prove or disprove the justification of an apparent glycol LTS application.

From economic criteria established, two trends appear to be developing regarding the application of LTS and stabilization equipment. First, there is an indication that in most cases in the future, the type of LTS that will be installed will be either of the abbreviated-mechanical or the glycol-injection process. Second, there is another trend developing which indicates that in almost every case of a glycol LTS installation there will be a companion installation of a cold-feed stabilization system.

Development of low-temperature separation and stabilization processes is the greatest advancement in field separation and gas handling methods in recent times. Although the development of these processes will be further refined in the future, their use already has been and will continue to be very profitable to the industry.

Operator's Comments

El Paso Natural Gas Company operates something like 400 different dehydration units in the San Juan Basin area, plus a large number in the Permian Basin. These units vary in size of gas throughput from as low as 50,000 cu ft daily to as high as 300,000,000 cu ft per day. In the design stages now are plans to increase the latter units from 300,000,000 to 600,000,000 cu ft daily.

Three types of dehydration units are operated by our company — glycol, combination glycol-MEA, and dry bed. Glycol units are primarily wellhead units, and the majority of them are in the San Juan Basin. There are also three units that might be called fixed-plant glycol installations with capacities of 25,000,000 to 50,000,000 cu ft daily.

The combination glycol-MEA units are used primarily for treating sour gas, but at the same time, they also effect considerable dehydration. We have found MEA to be a bit better than glycol as a dehydrating agent, and thus we lose nothing in the way of dehydration in these processes.

Dry-bed units are on the input ends of the main trunk lines. There are two of these in the San Juan Basin and several in the Permian Basin division. These units are operated downstream of all plant facilities, giving us a "last crack" at the gas before it enters the main trunk lines.

Determining Type to Use

First consideration is the downstream gas specifications. In El Paso's gathering system, we are not bound to any given water content, and reducing water content to a minimum is not a chief factor. We are interested in getting it low enough so that the gas can be moved to the plant. This usually can be done with a 20-deg dew point. Therefore, the logical unit is a small glycol unit, skid-mounted for field operations, that will drop the dew point of the gas 50 to 55 F. Most units will do better than that, but a 50 to 55 F drop will prevent freezing in the lines following the dehydrator.

On main lines, this problem is different. Not only the freezing effect must be considered, but also the removal of such things as entrained oils, amine glycols, and other materials that might occur in the gas stream after leaving the plant. These have to be kept out of the pipe line. To accomplish this, dry-bed units are used.

From the San Juan area, our lines go west into the high mountain country, where it's desirable to keep water content as low as possible in order to keep city taps enroute from freezing when they make pressure reductions.

A second major consideration is the inlet gas condition. If incoming gas is sour, we use the glycol-MEA system to remove hydrogen sulfide or CO_2.

Inlet gas temperatures also are important. If gas coming in is 110 to 120 F and you need 15 to 20 F dew-point gas going out, you can't use glycol dehydration. You will need some precooling of the units in order to get gas temperatures down to where glycol units can reduce dew points to the levels desired.

If you have a given dew-point depression—say, 55 deg—with a 95-deg gas coming in, you have a 40 F dew-point coming out. If you have 75 F gas coming in, you have 20 F dew-point coming out. Thus, the inlet temperature is going to regulate, to some extent, the dew point coming out of the glycol unit. Knowing the inlet temperature helps decide whether to use a glycol unit or a dry-bed unit that will operate at slightly higher inlet temperatures and still give good outlet dew points.

Another consideration is incoming liquids. We find that we have glycol amine leaving our gas processing plants. It may sound peculiar, but we put a dry-bed unit downstream from a glycol unit strictly as a glycol-amine removal unit.

In some cases where we have both gasoline and treating plants, we combine the stream before dehydrating them. Gas coming out of the gasoline plant has not been previously dehydrated, except for the field units. This gas, to meet our operating conditions, has some water put back into it. It is then necessary to dehydrate this gas with a minimum of entrained liquids; therefore, we combine it with the gas out of our glycol-amine units for further dehydration.

A major factor that must always be considered is cost. Our cost is based on what we get for each dollar spent. If you spend money on equipment that won't do the job, it can be very expensive. It's better to pay a little bit more on something that will do the job.

Operating Problems

Operating problems fall into several classifications. The first category is strictly mechanical problems. There are few things in glycol and dry-bed units that can give you trouble. The two things that can be most critical in unattended field units are the pump and the pilot line. Many things go wrong with a field unit, and still it will work. But if a pump stops or a pilot light goes out, the unit is down. Check valves are a source of some trouble, but not too often. Control valves give difficulty in colder temperatures and freezing weather, being particularly susceptible to rocks, trash, and various other items coming out of the well bore, which get to these valves and leave them slightly off their seats. This is especially true in an area like the San Juan Basin, where you are always on the verge of freezing, and this extra cooling will freeze them quickly.

With dry desiccant units, a major source of trouble is bed attrition. It might not happen often, but when it does, it is serious trouble. If a bed begins to "dust" and go down the pipe line, it's wise to inform the next com-

pressor station up the line of this condition so they will have time to get a supply of packing on hand. Packing will remove the dust, but it takes some time to do it.

To overcome bed attrition, we try to over-design just a bit to keep velocities low enough so that the bed won't move. One of El Paso's repair men claims that the dust from these beds is one of the best rouges he has ever seen for use in a compressor engine to "seat in" the piston rings.

Attrition has two major causes. One of these is under-design, that is, too high a velocity through the bed. The other is channeling in the bed. A vessel can be designed with the proper flow characteristics if everything is right. But it also can be designed so that a leaking screen can block off part of the bed and divert the entire flow over another portion. Once this starts, the only way to stop it is to take everything out and start over.

In operating a dry-bed unit, a common problem is fouling the bed. One cause is hydrogen sulfide, which, in some manner, causes the dry desiccants to lose their ability to pick up water. Oils or other liquids can also foul the bed.

What about operating units designed to take out glycols, amines, absorber oils, and other materials without the high expense of bed replacement? El Paso's units are designed with a precontractor, which is about one-third of the total bed, over which the gas has a "down flow." Gas then goes under the bottom and has an "upflow" through the remaining two-thirds of the bed.

On regeneration, flow is reversed, bed temperature is increased to about 350 F, and about 200 gal of water are injected into the hot regeneration of gas. This steam seems to bring out nearly 100 per cent the trapped oil, glycol and amine. This might not work in some areas where heavy absorption oils are used. We use, however, a relatively light oil—kerosine—and it works well, not only in keeping the bed clean, but in recovering these materials.

Cold weather always provides troubles. It requires keeping control valves that handle water warm enough so they cannot freeze. Anything with water in it in our San Juan area will freeze. We have trouble with formation water, which is not salt water, freezing in the top of the separator, at the bottom, and all through the unit.

We use the waste heat from our glycol units to heat separators, control valves, control heads, dump lines, and anything on the unit that might handle water.

In this way, we keep these units operating. One thing that does shut down the unit, however, is having the glycol freeze up. This happens infrequently. Freezing in any part of the controls will give trouble. If the dump valves freeze, liquids go into the dehydrator, and eventually go out the top of the still or down the pipe line. Both are trouble.

Fire Hazards

Some glycol units have direct-fired reboilers. These can be serious sources of fire. If a gallon or so of hot distillate collects in the bottom of a dehydration contactor and then is dumped into a hot still, it doesn't stay there long. Generally it comes out the top, and in some cases, the material has sprayed out over a unit and started a fire.

In another case, a drip on a gas fuel line to a reboiler became loaded and dumped into a reboiler firebox and started a fire.

We are working on means to put fire streams on the reboiler burner and to find a way to catch the condensate before it can get into the boiler box. In this way, we hope to stop the possibility of fire on these units.

A broken line is always a source of fire. On dry-bed units, with direct-fire regeneration heaters, common fire hazards are broken lines, burned tubes, or anything that will allow free gas in the area.

Conclusions

In selecting a unit for dehydration operations, the first thing to consider is cost—because management is going to be very interested in that.

Second, take a long look at the gas that's going to be processed—because the operating costs of a unit will be determined largely by the characteristics of that gas.

Third, consider how you can take inlet gas and make it meet the downstream gas specifications.

Fourth, make sure of good operating condition—how easy will it operate and how dependable will it be?

Manufacturer's Comments

The most important item to consider in the design of solid-desiccant type dehydration units is the inlet conditions, both pressure and temperature. This type unit has to be designed for the lowest predicted pressure and the highest predicted temperature. An examination of water content curves will indicate the major importance of temperature.

Precooling of any type should be considered on any large dehydration installation. For every 20 F reduction in inlet temperature, the water load is decreased by 50 per cent. The plant with an inlet temperature of 140 F requires about four times as much desiccant as one handling the same amount of gas at 100 F inlet temperature.

The greater amount of desiccant required to handle high inlet temperatures is responsible for other undesirable features, one of them being the effect on operating costs. Higher regeneration heat loads required due to high inlet temperatures necessitate the use of larger quantities of gas and bigger heaters. Of course, to a gas transmission company maybe that gas has cost them from 12 to as high as 20 cents per thousand cubic feet, and it becomes an economic consideration. These high-capacity desiccants will dehydrate those high inlet temperatures, but at the same time, don't forget to consider precooling of some character, predominately water, before going into a solid desiccant dehydration unit where high inlet temperatures are involved.

High inlet temperatures are also responsible in an indirect way for bed contamination from heavy oils. With high inlet temperatures, more of the lubricating oil or heavy ends are carried in the vapor phase into the desiccant. These are more difficult to remove, have a tendency to contaminate the bed, and are responsible to a certain degree for lowering the capacity of the desiccant over its operating life.

The second consideration is the pressure drop requirement. Pressure drop to the gas industry, and particularly to the transmission companies, is the same as dollars. One transmission company values a pound pressure drop worth $2000 on a plant handling 35,000,000 cu ft of gas at 300 psi. For 5 psi it's worth $10,000, or to put it on the basis of a 140,000,000 cu ft plant operation at 300 psi, it would be worth $40,000. It would be economical to spend at least $40,000 reducing the pressure drop 5 psi in a plant handling 140,000,000 cu ft of gas at 3000 psi. Therefore, pressure-drop consideration is strictly an economic problem. Of course, there is an absolute minimum, and that usually runs in the range of from 3 to 5 psi. That's the usual drop through a solid desiccant bed. It would be difficult to go lower than that.

In large plants of 200,000,000 cu ft per day and above, compressors are used to flow gas out through the regeneration heater and back into the system to reduce the pressure drop normally encountered in the split-flow type of dehydration plant. This idea

reduces considerably the pressure drop inherent in a solid desiccant plant and is used to very good advantage. The major source of pressure drop is in the piping and the valving. That is, provided of course, that the bed velocity is maintained at a proper rate. If the bed velocity is kept down to the point where bed attrition is not a problem, then the pressure-drop characteristics of the bed are good when a normal 7 lb per million contract specification must be met, 25 ft per minute superficial velocity through a solid desiccant bed is normal practice. When going to very low dew points (in the order of zero or below), velocities of 15 ft per minute or velocities more in line with those that will obtain low exit dew points should be considered. The slower the gas moves through the bed, the more complete is the degree of dehydration. The industry now finds it necessary to go to minus 80 deg dew points, in which case it is essential to use double valving and bleeders between valves to prevent leaks from the wet side to the dry side. Also, very low bed velocities are needed to reach the outlet at this low dew point.

Desiccant Capacity

Raw bauxites and refined bauxites are not usually applicable to high inlet temperature conditions. We use a design capacity of 5 per cent on 80 F inlet temperature and about 1½ per cent on 110 F inlet temperature. If the gas temperature runs high, the economic limit as far as bauxite is concerned is rapidly approached.

High-capacity desiccants (siliceous beads or the silica aluminate pellets) have excellent application on inlet temperatures as high as 140 F. For reasons outlined previously, precooling should be considered when dealing with such temperatures.

Serious consideration should also be given inlet-separation equipment ahead of any dehydration plant. In plants receiving large volumes of gas, it is quite important in centrally located dehydration plants that ample separation equipment ahead of it be used. In some cases, two separators in series with large liquid discharge valves may be justified in order to dump all the liquids. In a 20,000,000 cu ft—unit, the investment in desiccants ranges from $3000 to $5000. It seems ill-advised to be skimpy on inlet separation equipment ahead of a unit of this size.

Direction of Regeneration

In the early days, downflow regeneration in a vertical tower was used to get away from reflux action or flotation of the fines to the top of the bed. This is not necessarily the best, and if a choice could be made, it would be downflow, upflow, downflow. But, this becomes complicated to accomplish regeneration automatically. To get the lowest dew point and the best regeneration characteristics, it is necessary to downflow on dehydration, upflow on regeneration, then start to cool the bed off and downflow again. As the bed is cooled, the raw gas is then dehydrated before it comes in contact with the lower part of the bed. And, the lower part of the bed is that section where it is necessary to maintain the lowest relative humidity, or the greatest dehydration capacity. To accomplish this end, the ideal situation is a downflow, upflow, downflow cycle. The problem is usually resolved by holding to a central downflow, upflow, or a downflow, downflow cycle.

Winterization

Solid-desiccant type units should be winterized for all weather operations in cold areas just as a separator or any other type of equipment handling water would be winterized. The best way found so far to protect a cold gas line leading to a big regeneration cycle subject to freeze-ups is to encase the gas line in insulation with the hot line running to the regeneration heater.

Load Factor

Unless towers are compartmented or some provision made for outside cooling, it is difficult on a straight gas-to-gas cooling or solid-desiccant type plant to operate at less than 50 per cent of its design load. Reason is the 125-deg maximum outlet temperature specification in many gas contracts, and the relations which exist when considerable cooling with incoming gas is performed, which heats up the gas and creates difficulty in the dehydration process. Obvious solution is to make special provisions in the contact towers if such a condition is anticipated, or to provide outside water cooling for the regeneration gas.

Glycol Dehydrators

Pressure drops are easy to keep low because the gas passes through one tower consisting of about four trays. The glycol circulation rate is well known. Usually about three gallons of glycol are required per pound of water in the gas. Good inlet separation equipment is important in glycol units just as it is in solid desiccant types. Salt water in the glycol system causes considerable trouble. Salt deposits out in the glycol reconcentrator. Oil in the glycol aggravates foaming and causes a fire hazard.

Use of an outlet scrubber on the discharge of the tower, particularly in large plants, should be considered. Variation in flow rates or upset conditions that exist in a tower may result in a loss of glycol unless some type of scrubber is installed on the downstream line.

It's desirable in a glycol unit to maintain low heat-flux densities in the reconcentration equipment. This is apparent when it is considered that glycol has a tendency to break down if heated to high temperatures. The system should also have some type of oil skimmer and gas eliminator ahead of the concentrator. This will reduce foaming and will also have some tendency to reduce glycol losses. Gas in the still has a stripping effect on glycol and tends to carry with it some of the glycol at equilibrium temperatures as it exists from the top of the still. It's also desirable to have a filter on the glycol system to keep it clean at all times. Good temperature controllers and liquid controllers are a must. It is especially desirable to have the fire tubes in the reconcentrator removable so they can be cleaned.

Low-Temperature Separation

Experience has indicated the importance of designing flexibility into centrally located, low-temperature separation installations. Such installations should be able to operate with or without glycol. In so many cases, wells produce more than just gas distillate, and any contaminant from any one well will contaminate the entire system as far as glycol is concerned. After wells clean up, glycol can be used without getting contaminated. The system should be capable of operating with or without a stabilizer, and it should be able to operate when heavy paraffin particles or paraffin components are present. It's impossible to predict when paraffin substances will start giving trouble.

Well Performance Data

When discussing low-temperature applications, it is important to know wellhead flowing temperatures versus volume or flowing rates. These data determine the heat exchange in this type unit. If wells hydrate the tubing, it is necessary to recognize the fact and plan for it in the original equipment. If the wells flow at 180 F, this fact should be known too. The U. S. Bureau of Mines' back pressure test procedure is a valuable tool in predicting well performance. It is possible to determine what type unit to install, whether an abbreviated LTX or LTS system, or an abbreviated or full-fledged glycol injection set-up.

Precautions

In a field or gathering system taking gas from a few wells and delivering the gas to a transmission company, an indirect heater is preferable to the direct-

XUM

fired heater. In a direct-fired heater, a large quantity of heat is stored in the insulation. If the flow should freeze up or stop quickly on the inlet side of the direct-fired heater, residual heat in the refractory insulating material encasing the tubes has a tendency to raise the temperature of those tubes beyond the yield point and may cause trouble. As a matter of fact, a few direct-fired heaters have blown up as a result of freeze-offs, of the gas going to the regeneration heater.

Questions and Answers

Q. What is MEA?

A. MEA stands for Monoethanolamine. It is used primarily to treat out H_2S and CO_2 in gas.

Q. Is it generally economical to insulate a cold separator and heat exchanger on the low-temperature units?

A. In the mechanics of heat exchange, the salvation of one degree of temperature in a system will generally result in the lowering of the well stream through the heat exchanger about 2½ to 3 F, depending on the size of the heat exchanger. If the operating temperature in a glycol unit increases due to pressure decline, a loss in recovery might result. Maintaining as low a temperature as possible is important here, and insulation will help do that. If a heat exchanger hydrates up because of loss of glycol or improper glycol distribution, insulation would make it difficult to thaw out the unit.

Q. It has been pointed out that LTS units should be designed for flexibility. One of the points covered was paraffin. How do you handle this problem if paraffin is present?

A. If you have vapor-phase paraffin components present, the best thing to do is provide heat in the base of the unit to keep the temperature of the liquid portion of the low-temperature vessel above the point where paraffin tends to solidify. Ordinarily, a temperature of 50 to 60 F (the hydrocarbon temperature) will keep these heavy paraffin ends in solution. Heat can be provided by low-pressure steam, hot water, or by the hot product from the stabilizer.

Q. What is the best means of getting corrosion inhibitors that carry paraffin around the glycol reboiler?

A. Experience has indicated that it is not too much of a problem where heat is used in the base of the vessel. This is true where you use the inhibitor in a glycol injection system. Trouble will occur where a low-temperature vessel is used only for dehydration and the distillate and gas are recombined and transported simultaneously (as in offshore operations). Another company's experience has been satisfactory, but costly, where free liquids are bypassed around any contact with the glycol. These liquids are dumped from the free water knockout to a secondary vessel, then to the stabilizer. This gives the flexibility needed in LTS units.

Q. What is the best method for calculating the time required for heating and cooling a solid desiccant bed? Some firms use an average exit temperature of 220 F for heating and an average of 165 F for cooling. On that basis, they calculate the time required to remove all heat plus the heat required to cool the tower. Is there any good accepted procedure besides this one?

A. Generally, in a given solid dessiccant dehydration unit, the system is designed so that two-thirds of the heat supplied goes into sensible heat and the other one-third is the heat of vaporization of the water, hydrocarbons, etc., that are absorbed in the system. If you want to regenerate quickly, you can heat it in several ways: One cycle is to heat up in 4 hours and cool off in 2, for a 6-hour cycle; another is to heat up 8 hours and cool off in 2. Normally, you would use an 8-hour cycle, with 6 hours of regeneration and a terminal temperature of 350 F on regeneration, and then cool down to 140 F.

Q. The figure of 220 F was not the effluent temperature; it was the average used to calculate the time. And the 165 F seems to come out fairly well for calculating the cooling time and amount of gas needed.

A. Those would be good average figures.

Q. What effect does the per cent moisture in the gas, compared to the amount it would have in saturation, have on the efficiency of the desiccant bed?

A. The effect of relative humidity on desiccant capacity is a dynamic desiccant capacity. It is usually ignored, assuming that the gas is saturated, because desiccant capacity falls off almost proportionately to the lower relative humidities as the water content decreases. It is almost a parallel of linear function. If gas originates in the field at 80 F, it probably will be 110 F inlet temperature, due to heat picked up in the lines transporting the gas. Many companies use this assumption and several have developed curves giving the relationship of desiccant capacity and the per cent of relative humidity of the gas entering the unit. It's much more practical just to assume a 100 per cent saturated condition.

Q. Isn't there a new desiccant material available that has a high capacity?

A. The designation of that material is H-151. It is a silica alumina, a pelletized material available in two sizes, a ¼-in. ball and a ⅛-in. ball. They are very hard, do not break, and have a low attrition loss. It is now being tested.

Q. What velocities do you design for a unit to be installed in an area such as South Texas?

A. If you use a 7-lb per million cubic feet contract specification as a criterion for exit dew points, stay within the limits of 20 to 25 cu ft per minute. Some users want lower dew points and use 15 cu ft per minute as a superficial velocity.

Q. How low can you get in pounds per million in a solid desiccant? Could you get down to 2 or 3 lb per million?

A. Absolutely. Dew points in the order of —80, —90 or even —100 F are being used. In a plant in East Texas, a —140 F dew point is being used. In the "Operation Gas Liquification," a turbo-expander is used, and a —80 F dew point is required.

Q. Can you use solid desiccants for expander operation?

A. Certainly. In expander operation, you have other things, such as CO_2 removal, to consider. Solid carbon dioxide will form and "pile up" on the wheels of the turbo-expander and cause trouble.

Q. What about water in scrubbers?

A. Get it out of there immediately. Scrubbers should drain out any water that collects in the bottom. Use a smaller pipe into another vessel and then let that vessel drain into the atmosphere. If the water isn't removed, gas can pick up quite a bit of it and cause trouble.

* * *

PERSONALS

Robert E. Cashen has been appointed manager of the petroleum department of The First National Bank, Shreveport, Louisiana. Prior to accepting the new position, he was employed by Stanolind Oil and Gas Company as a petroleum engineer in the Ark-La-Tex and Mid-Continent regions.

Mrs. Bunnye Lerner of Denver, Colorado, has been named supervisor of the women's program for the Oil Industry Information Committee. Mrs. Lerner, administrative assistant in the Denver OIIC office, will move to New York City in the near future. She succeeds **Miss Marceline Marquis,** who has resigned to be married. Mrs. Lerner has been with the Denver OIIC office since 1951, having begun as a stenographer and working her way up to administrative assistant.

James W. Foley has been named executive vice president of The Texas Company. He was elected a vice president in 1953, and a director in 1954. Foley is also a director of Arabian American Oil Company, the Trans Arabian Pipe Line Company, Texaco Exploration Company, Colombian Petroleum Company, South American Gulf Oil Company, Coltexo Corporation, and The Texas Company (Iran). Foley joined The Texas Company in 1932 after being graduated from Texas A&M College with a BS degree in petroleum engineering. Following service abroad with the Bahrain Petroleum Company, Ltd., in which Texaco has a 50 per cent interest, he held various positions in The Texas Company's domestic producing department, later serving as assistant to the manager and as assistant to the vice president in charge of domestic producing. In 1950, he was appointed assistant to the chairman of the board.

J. W. Foley

Herbert Rothstein has been named vice president of Bell Oil & Gas Company, and **Joel P. Dyer** has been made secretary. **E. S. Horner** will be the new manager of refining but will continue as superintendent of the Ben Franklin Refining Company refinery at Ardmore, Oklahoma. Ben Franklin is a wholly owned subsidiary company.

James Taylor Ponder has become executive vice president of Kin-Ark Oil Company. He had been general manager for Curtis Kinard, independent oil operator at El Dorado, Arkansas.

Ray Althouse, formerly of Bartlesville, Oklahoma, and now of Calgary, Alberta, Canada, is now president of Royalite Oil Company. He went to Calgary in 1952 to become executive vice president of Royalite.

T. S. Peterson, president of Standard Oil Company of California, has been requested to serve as businessmen's represenative on President Eisenhower's committee for traffic safety.

John Guynes has been elected chairman of the Oil Industry Buyers Group of the National Association of Purchasing Agents. He is purchasing agent of the Magnolia Petroleum Company, Dallas, Texas. Guynes succeeds **A. R. Eimer** of Standard Oil Company of California, San Francisco. After receiving a degree in textile engineering from Texas A&M College in 1931, Guynes joined Magnolia. He had worked in the oil fields near Beaumont, Texas, before going to Magnolia. On loan during World War II, Guynes served six months with the Petroleum Administration for War working out allocations in the tubular goods field. He was elected president of the Dallas Purchasing Agents Association that some year, and has also been active in the Dallas-Fort Worth Oil Buyers Group.

John Guynes

Sunray Mid-Continent Oil Company and its subsidiary, D-X Sunray Oil Company, both of Tulsa, Oklahoma, have announced the combination of the personnel, employee relations, and safety departments of the two companies and the appointment of **George F. Bush** as manager and **Forney Hutchinson Jr.** as assistant manager of the new department. The departments of the two companies have been combined to achieve greater operating efficiency, **W. R. Loren** has been named assistant eastern division manager, distributor sales, for D-X Sunray, and **W. W. Neddo,** formerly district sales manager, Anderson, Indiana, has been made assistant division manager.

Gavin Witherspoon has been named vice president and general manager of American Independent Oil Company to reside in Kuwait, Persian Gulf. Witherspoon, formerly vice president of Bahrain Petroleum Company, has had extensive experience both in the United States and in the Middle East in operational aspects of the oil business and in intergovernmental relations.

William R. Waag has joined The First National City Bank of New York, New York, as petroleum engineer in the petroleum department. Until recently he had been senior engineer, specializing in oil reservoir engineering, with the Sohio Petroleum Company, Oklahoma City, Oklahoma, a subsidiary of Standard Oil of Ohio. He represented the company on unitization projects in which several major oil companies would pool their interests in producing oil properties, and served in the Mid-Continent area from Canada to the Gulf Coast. Previously Waag had been associated with Plymouth Oil Company in Sinton, Texas. Waag attended the University of Pittsburgh, Pittsburgh, Pennsylvania; the Missouri School of Mines, Rolla, Missouri, and was graduated from Pennsylvania State University at University Park, Pennsylvania, with a BS degree in petroleum and natural gas engineering.

W. R. Waag

H. G. Meador

W. L. Naylor

R. O. Rhoades

T. J. Sullivan

R. L. Boggs

Directors of the Gulf Oil Corporation have designated four vice presidents, who together with the president and executive vice president, will constitute the newly created management committee. The senior vice presidents are **H. G. Meador,** formerly vice president, domestic marketing; **W. L. Naylor,** formerly vice president and comptroller; **R. O. Rhoades,** formerly vice president, production, and **T. J. Sullivan,** formerly vice president, manufacturing. Four new vice presidents elected are **B. H. Barnes** and **Dr. Jerry McAfee,** manufacturing; **R. L. Boggs,** production, and **Dr. B. B. Wescott,** research. New comptroller is **F. B. Branson.**

Charles A. Chipman of Bolivar, New York, has been reelected to his third one-year term as president of the Pennsylvania Grade Crude Oil Association. Other officers reelected include **George J. Hanks,** chairman of the board of South Penn Oil Company, Bradford, Pennsylvania, first vice president; **A. C. Simmons,** Simmons Oil Company, Bradford, second vice president; **Fayette B. Dow,** Washington, D. C., vice president and general counsel; **Samuel Messer,** Quaker State Oil Refining Corporation, Oil City Pennsylvania, treasurer; **F. W. Alcorn** and **C. L. Suhr,** both of The Pennzoil Company, Oil City, and **C. G. Johnson** of Quaker State Oil Refining Corporation, Oil City, assistant treasurers, and **W. C. Wenzel,** executive manager.

John M. Clark has been named supervisor, building services group, Caracas, Venezuela district, for Creole Petroleum Corporation. **Ralph L. Dales** has been appointed supervisor, community integration section, industrial relations department, Caracas, for Creole Petroleum. This position was recently created.

Milton C. Hoffman, for many years associated with Stanolind Oil and Gas Company, Tulsa, Oklahoma, has been elected a vice president of Continental Illinois National Bank and Trust Company of Chicago, Illinois, in which capacity he will be active in the field of oil and gas financing.

DEATHS

W. W. ("Web") Wilson, founder and chairman of the board of Web Wilson Tools, Inc., died in Los Angeles, California, recently following a long illness. Wilson was born in Parsons, Kansas, and came to California in 1886, where he was later graduated from Stanford University. He was a 32nd deg Mason.

Miss Mary Alexander, assistant to the late Dr. Gustav Egloff, who was director of research for Universal Oil Products Company, died recently in her Chicago home after a three-week illness. Her death came almost two months to the day after that of Dr. Egloff, with whom she had been associated since 1939.

Very active in local, divisional, and national affairs of the American Chemical Society, of which she had been a member for 16 years, Miss Alexander was to have taken office July 1 as secretary of the Chicago Section. In national activities of the ACS, Miss Alexander was a member of the women's service committee in 1951, 1952, and 1953.

John G. Norton, a director and chief mechanical engineer of Magnolia Pipe Line Company, died recently at Dallas, Texas, after a long illness. A native of Massachusetts, Norton was graduated from Northeastern College in Boston. After several years' engineering work in Puerto Rico, he joined Magnolia in 1927. He was elected a director of Magnolia Pipe Line in 1953.

Allen V. Riley, technical sales representative for Atlas Powder Company in Houston, Texas, area, died recently after an extended illness. Riley, a native of San Saba, Texas, received his degree in chemical engineering from the University of Minnesota and worked for several constructions firms before joining Atlas as a chemist in 1948. He had been in sales since 1951.

Harry L. Moat, director of production for the Atlas Powder Company explosives department, died recently at his home in Wilmington, Delaware. He and Mrs. Moat had just returned the day before from a meeting at White Sulphur Springs, Virginia, of the Institute of Makers of Explosives, on whose technical committee he served. A native of Catasaqua, Pennsylvania, Moat was graduated from Pennsylvania State College, where he was a member of Phi Kappa Phi, honorary scholastic fraternity.

Earl J. Robishaw, vice president of A-1 Bit and Tool Company died in Houston, Texas, recently. A graduate of Texas A&M College, he worked for the Texas Company and was with A-1 for 18 years. Robishaw was a charter member of the Nomads, a member of the Houston Club and A&M Club.

W. R. Kubista, formerly chief engineer of the Oklahoma Natural Gas Company, died recently and has been succeeded by **M. J. Peterson.**

Edward W. Johnson, manager of process pump sales for the Oil Well Supply division of United States Steel Corporation, died recently at Dallas, Texas, after a brief illness. A native of Saratoga, Texas, Johnson was graduated from the University of Texas with a degree in mechanical engineering and later taught at the university.

Wayne C. Yeager, former director, vice president, and general manager of sales of The Atlantic Refining Company, died recently in a hospital at Allentown, Pennsylvania. He had served with Atlantic for 53 years when he retired in 1949.

In 1920 he was named manager of the southern division of the domestic sales department in Atlanta, Georgia. In 1935 he was made vice president and general manager of domestic sales at the company's headquarters in Philadelphia. He was also elected a director in 1930.

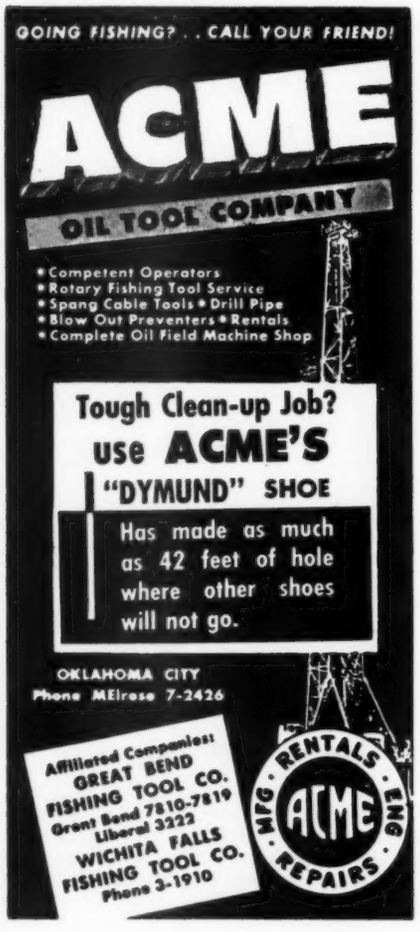
He was elevated to the newly created post of general manager of sales, which he held until his retirement two years later.

Howard R. Huston of New York City, retired vice president and director of American Cyanamid Company, died recently at his summer home at Truro, Massachusetts.

Huston was born in Sweet Springs, Missouri, and later moved with his family to North Dakota. He received his BA degree from the University of North Dakota, where he was also awarded an honorary MA degree. After the World War I Armistice, Houston was named Secretary to the General Staff of the Army of Occupation in Germany.

Bernard A. Montgomery, Kew Gardens, New York, staff executive of the accounting department of Cities Service Company, died recently following a long illness.

Thomas A. McElhaney, a member of BJ Service, Inc., Long Beach, California, died at his home recently. He had been recently promoted to the position of Pacific Coast division sales supervisor.



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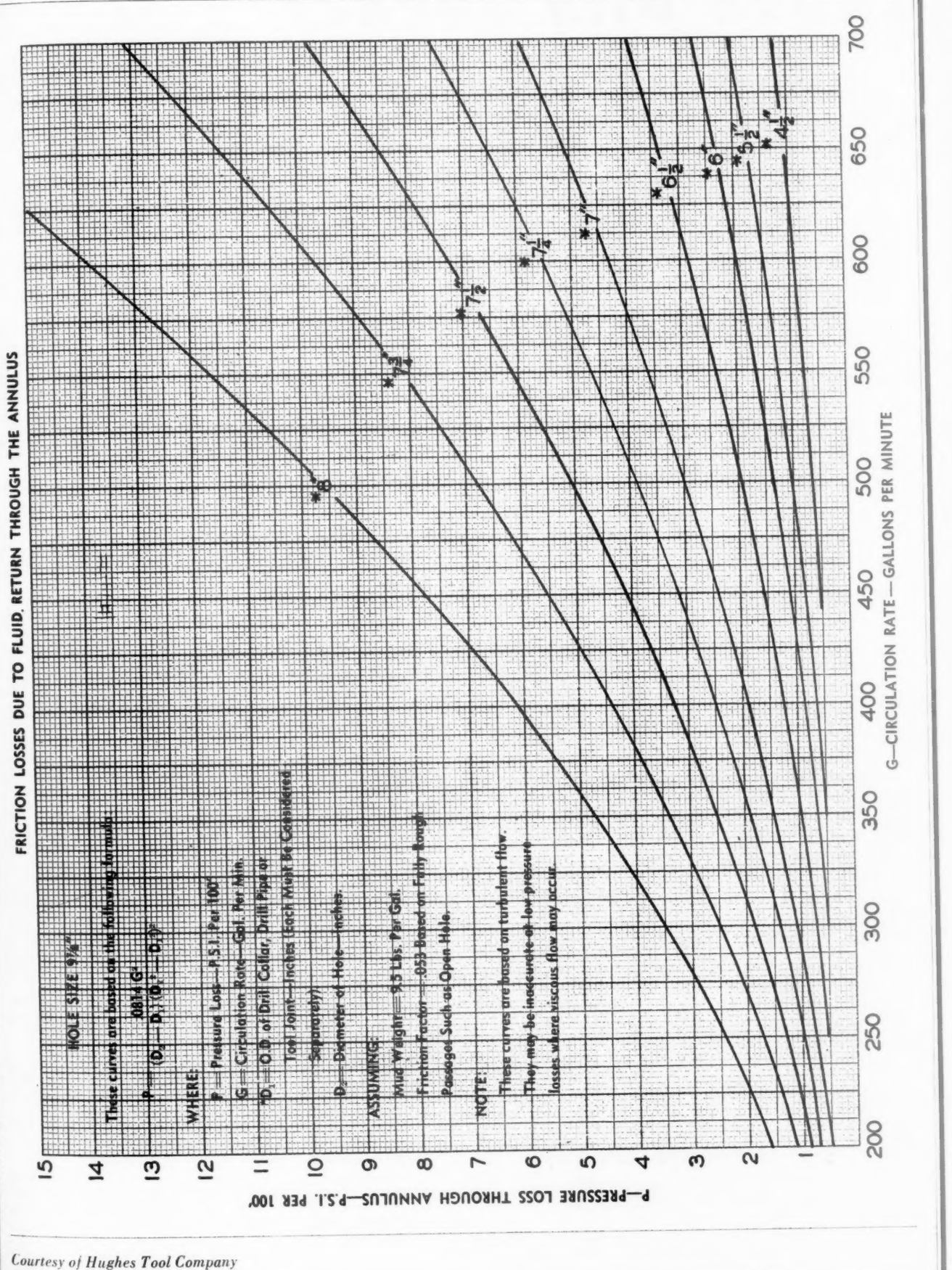


Courtesy of Hughes Tool Company

LAUGH with BARNEY

And then there was the guy who took his defeat like a man. He blamed it on his wife.

You know they also have a slogan in Russia: "Vote for the party. The life you save may be your own."

Just as we begin to get adjusted to loafing a bit, it's Monday morning.

J. E.: "Mary, who was that man I saw you kissing last night?"
Mary: "What time was it?"

Keeping up with the Joneses isn't nearly as dangerous as trying to pass them on a hill.

TV Announcer: "We have just received a bulletin of a catastrophe, the like of which has never been known to mankind —but first, a word from our sponsor."

Nobody expects to find the perfect girl, but it's sure lots of fun hunting.

A fool and his money are *invited* places!

Susie, the receptionist, says that the blonde who can keep her hair light and her past dark is always happy.

"Marriage gives single men a new lease on life at double the rent."

The noblest of all animals is the dog and the noblest of all dogs is the hot-dog. It feeds the hand that bites it.

Some folks don't go through life—they're shoved through it.

A man stood on a California street corner several hours, waiting to cross. After awhile, he spied a pedestrain on the opposite side of the street. "How'd you get over there?" he shouted.
The other yelled back, "I was born over here."

Father: "Don't you think our son gets his intelligence from me?"
Mother: "He must. I still have mine."

A Russian named Rudolph looked out the window one morning and said, "It's raining."
"No, its sleeting," said his wife.
"It's raining, doggone it," he answered, "And Rudolph the Red knows rain, dear."

Sue: "I want to know if I have grounds for divorce."
Lawyer: "Are you married?"
Sue: "Yes."
Lawyer: "Then of course you have."

Fellow was visiting in a state that once was Indian Territory. He stopped at a big school just south of the state's capital city and asked a big husky fellow, "Can you tell me the name of this school young man?"
"Sorry, I only play football here."

"Do you really love her?"
"Do I love her? Why, I worship the ground her father struck oil on."

She: I'll have you know that I intend marrying an oil man and a gentleman.
He: You can't. That's bigamy.

Philosophers say the best way to get the most out of life is to fall in love with a great problem or a beautiful woman.
"Well," admitted the pessimistic pipeliner, "I fell in love with the latter and now I have both."

Everyone likes to see a broad smile—especially if she smiles at him.

The salesman pulled into a strange town late in the evening and found the only hotel crowed to overflowing.
"Sorry, sir," said the desk clerk, "but we have nothing at all. Unless . . ."
"Unless what?"
"Unless you'd be willing to share a room and sleep with a red-headed school teacher."
The salesman drew himself up indignantly and said: "A red-haired school teacher! I know you've heard stories about traveling salesmen, but I'll have you know that I'm a happily married, church-going, home-loving man!"
"Well," said the clerk, "so is he."

On a street in Cairo, six Egyptians attacked an Englishman while a policeman stood idly by. "Aren't you going to do something?" inquired an excited onlooker.
"Why, no," said the cop. "Six should be enough."

Mountain climbers rope themselves together because there's safety in numbers. It also keeps the sane ones from going home.

Mrs.: I don't believe Jane's young man is just all we thought he was.
Mr.: What's the trouble?
Mrs.: Well, he hung his hat over the keyhole.

"Shore wish I had my wife back," sighed the hillbilly.
"Whar is she?" asked a friend.
"Sold her for a jug of moonshine."
"Reckon you beginning to miss her."
"Nope. Thirsty again."

A petroleum engineer who had spent much time out of the country, returned to retire in his native Southwest. After being back a short time, he became ill, and the doctor diagnosed the illness as hydropsy.
"What's that?" he asked the doctor.
"Too much water in the body," replied the sawbones. But the old engineer, flushed with years of tippling, was indignant.
"How could that be? I've never drank a drop of water in all my life." He was momentarily reflective.
Then, sadly, he remembered: "Must have been that blasted ice."

The driller said he missed his wife's cooking—every chance he got.

Motto for all employees to follow: "Make sure you are underpaid."

As the movie starlet described the elderly producer, "He may be old but he's still in there pinching."

A drill-bit peddler came home one night and flopped into bed. His wife said to him, "I put your shirt on the clothes horse, dear."
Absent-mindedly, he answered, "What odds did you get?"

A guy with a strip of bacon wrapped around each ear and a fried egg on his head walked into a psychiatrist's office.
Said the psychiatrist, "What's your trouble?"
The goof smiled and replied, "Nuthin' the matter with me, Doc. I wanna make an appointment for my brother."

A traveling salesman we know dashed to the airport only to find that the flight had been canceled. So, he returned home unexpectedly, walked into the bedroom, looked around, and made for the bathroom.
In his hand, he held a straight razor, stropping it vigorously. His wife opened her eyes and looked at him. "What are you doing, Horace?"
"If those shoes sticking out from under the bed have no feet in them, I'm going to shave."

You can tell a married woman by the ring on her finger, but of course, you can't tell her much.

Every time you tell a good story, you have to listen to two poor ones.

A physics professor called on a petroleum engineering student to list some characteristics of heat and cold.
"Things expand in heat and contract in cold," said the potential PE.
"Give an example."
"In summer," answered the student, "the days are long and in winter the days are short."

Salesman: "This model has a top speed of 100 miles per hour, and she'll stop on a dime."
Prospect: "What happens after that?
Salesman: "A little putty knife comes out and scrapes you off the windshield."

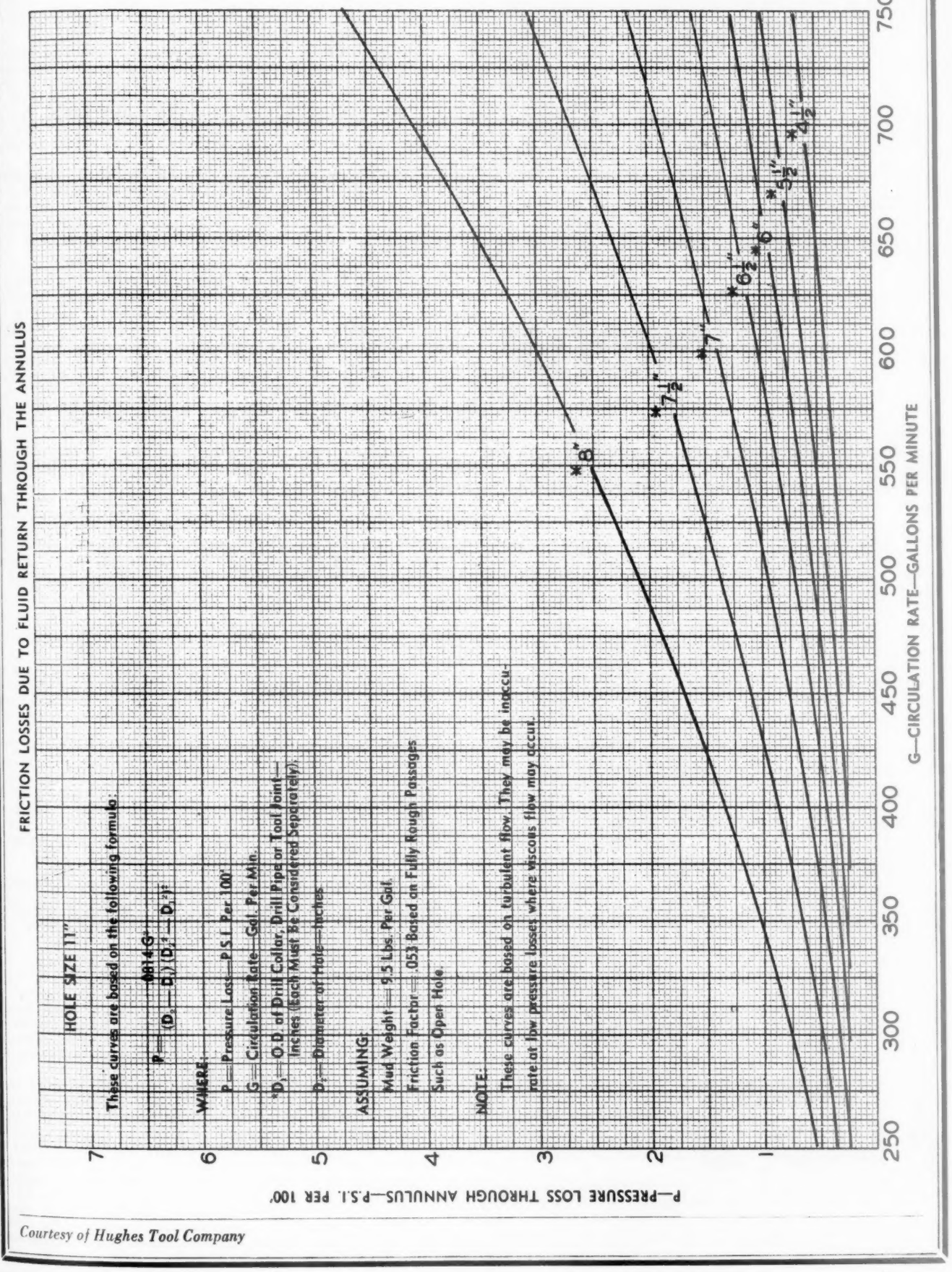
"If I came home and found an oil-man in my apartment," gasped the curvacious blonde in the chorus line, "I wouldn't know what to do."
"Well," suggested the girl in the next chair, "you could give him 48 hours to get out."

Indians captured the wagon train and one of the young women asked the chief, "You're not holding me for ransom, are you big boy?"
"Not me," replied the chief. "Let Ransom get his own women."

Two ducks were walking down the street. One turned to the other and said, "Oh, quit trying to walk like a woman wearing slacks."

"Signs are appearing on factory executives' desks reading 'Caution! Engage brain before starting mouth.'"

DRILLING HYDRAULICS



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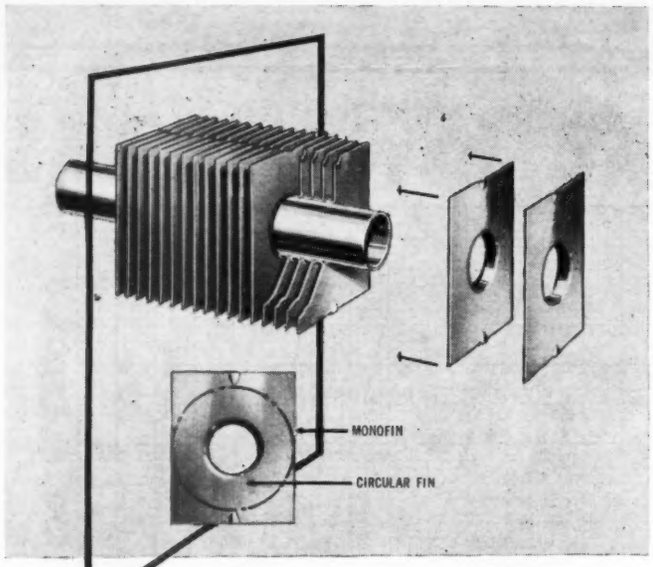

Monofin

New Young core provides seven times more heat transfer surface

Monofin Core, the most modern development in extended heat transfer, with seven fins per inch provides 58 per cent more extended surface. It also furnishes 7 times more heat transfer surface between tube and fin than a circular fin core with edge contact.

Young Radiator Company *Monofin* finned tubing is available with aluminum or copper fins, with various fin spacings for special applications. Tubing materials are copper, brass, steel or aluminum. Outside tube dimensions are ½", ⅝", ¾" and 1".

Monofin design features perfect mechanical tube to fin bond. It offers less resistance to air flow and more contact area between tube and fin. There is no solder bond to tube to hinder heat flow.

For further details, write for free bulletin to Young Radiator Company, Dept. 215-H, Racine, Wisconsin.

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BOOKS ★

Sonics, *by T. F. Hueter and R. H. Bolt, John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. Pages 456. Price, $10.00.*

Applications of sound (acoustical) waves to engineering and testing of materials has progressed so rapidly in recent years that this book is very timely. The first section is devoted to descriptions of the first and second order properties of different kinds of vibrations, giving especial attention to basic principles; analogy is drawn between acoustical and electric circuits, and that idea is employed throughout to simplify and illustrate the principles discussed.

The second part is devoted to methods for producing different kinds of mechanical "waves" or vibrations and utilization of these vibrations for chemical and physical or mechanical purposes. The reader is not required to know a great deal about physics nor acoustics. It gives an excellent bibliography of articles on this expanding subject.

Calculation of Static Bottom-Hole Pressure of Natural Gas Wells, *by Paul B. Crawford, R. I. Bradford, A. C. England and Henry Ince, published by the Texas Petroleum Research Committee, The University of Texas, Austin, Texas. Pages, 24. Price, $2.50.*

A method and manual of procedure has been developed by the Texas Petroleum Research Committee which facilitates the determination of the performance and potential of gas wells. An important item in such determination is the calculation of the static bottom-hole pressure from surface observations. The TPRC method not only increases the accuracy and ease of making such computations, but also greatly increases the reliability of the computations with the result that computation can be readily checked and errors found and discrepancies ascertained.

The bulletin, TPRC40, contains thirteen charts, the use of which is briefly and clearly explained by examples completely worked out. The Railroad Commission of Texas has authorized the use of the TPRC method and Bulletin 40 in the adjustment of the absolute open flow for the determination of the potential of gas wells required by statewide Rule 24 and the submission of the new Form GWT-4.

Hydraulic Pumping, *by Emory N. Kemler, published by Summary Reports, P. O. Box 176, Spring Park, Minnesota. Pages, 320. Price, $15.00.*

The ever-present demand for lower pumping costs and the more severe requirements of deep wells, place a continuing demand for new or improved pumping equipment. One approach to the pumping problem which has been used and is receiving increasing attention is hydraulic pumping.

This book summarizes a considerable portion of the patent literature relating to hydraulic pumping. Specifically it covers patents concerning bottomhole hydraulic pump-motor units, hydraulic surface units for actuating sucker rod pumps, and electrically driven bottomhole pumps. Also included is a bibliography of 30 articles dealing with hydraulic pumping, as well as a discussion reviewing some general principles applicable to this approach to the artificial lift problem.

A Professional Look at the Engineer in Industry, *prepared by the Engineer-in-Industry Committee, published by the National Society of Professional Engineers, 1121 Fifteenth Street, NW, Washington 5, D. C. Pages, 128. Price, $3.00 (to NSPE members, $1.50).*

If industrially-employed engineers and management are to resolve their industrial relations problems without resort to the divisive influence of collective bargaining for professional personnel, the solution must emanate jointly from the professional engineering society, industry and the professional engineers.

This is the conclusion of the Engineer-in-Industry Committee of the National Society of Professional Engineers in this recently-issued publication.

The publication reviews major causes of dissatisfaction among engineers in industry and the background and current status of drives to meet the engineers' problems by the development of engineers' unions. "Our studies have led us to the conclusion that there is no need for dividing engineers and managements into separate 'armed camps'," the Committee said. "Instead, the overall problem can be most satisfactorily resolved by cooperative efforts between enlightened management and forward thinking engineers." The Committee's study suggests a series of remedial actions by management and individual engineers in the fields of professional status, employment conditions and economic status.

UNIVERSAL CONVERSION FACTORS

FOOT PER DAY (Continued)

0.3048006	meters per day
0.0127	meters per hour
0.00021167	meters per minute
0.0000035278	meters per second
0.33333	yards per day
0.013889	yards per hour
0.00023148	yards per minute
0.0000038580	yards per second
0.3600	varas (Texas) per day
0.015	varas (Texas) per hour
0.00025	varas (Texas) per minute
0.0000041667	varas (Texas) per second
1.0	feet per day
0.041667	feet per hour
0.00069444	feet per minute
0.000011574	feet per second
1.33333	spans per day
0.055556	spans per hour
0.00092593	spans per minute
0.000015432	spans per second
1.515152	links per day
0.063131	links per hour
0.0010522	links per minute
0.000017536	links per second
3.00	hands per day
0.125	hands per hour
0.0020833	hands per minute
0.000034722	hands per second
3.048006	decimeters per day
0.127	decimeters per hour
0.0021167	decimeters per minute
0.000035278	decimeters per second
30.48006	centimeters per day
1.270	centimeters per hour
0.021167	centimeters per minute
0.00035278	centimeters per second
12.0	inches per day
0.50	inches per hour
0.0083333	inches per minute
0.00013889	inches per second
304.8006	millimeters per day
12.70004	millimeters per hour
0.21167	millimeters per minute
0.0035278	millimeters per second

FOOT PER HOUR =

0.0045455	miles per day
0.0001893939	miles per hour
0.0000031566	miles per minute
0.000000052609	miles per second
0.0073152	kilometers per day
0.0003048006	kilometers per hour
0.00000508	kilometers per minute
0.000000084667	kilometers per second
0.036364	furlongs per day
0.00151515	furlongs per hour
0.000025253	furlongs per minute
0.00000042088	furlongs per second
0.073152	hektometers per day
0.003048006	hektometers per hour
0.0000508	hektometers per minute
0.00000084667	hektometers per second
0.36364	chains per day
0.0151515	chains per hour
0.00025253	chains per minute
0.0000042088	chains per second
0.73152	dekameters per day
0.03048006	dekameters per hour
0.000508	dekameters per minute
0.0000084667	dekameters per second
1.45456	rods per day
0.0606061	rods per hour
0.00101010	rods per minute
0.000016835	rods per second
7.31521	meters per day
0.3048006	meters per hour
0.00508	meters per minute
0.000084667	meters per second
8.0000	yards per day
0.33333	yards per hour
0.0055556	yards per minute
0.000092593	yards per second
8.640	varas (Texas) per day
0.3600	varas (Texas) per hour
0.006	varas (Texas) per minute
0.0001	varas (Texas) per second
24.0	feet per day
1.0	feet per hour
0.016667	feet per minute
0.00027778	feet per second
32.000	spans per day
1.33333	spans per hour
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0.00037037	spans per second
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1.51515	links per hour
0.025253	links per minute
0.00042088	links per second
72.0	hands per day
3.0	hands per hour
0.05000	hands per minute
0.00083333	hands per second
73.15214	decimeters per day
3.048006	decimeters per hour
0.0508	decimeters per minute
0.00084667	decimeters per second
731.52144	centimeters per day
30.48006	centimeters per hour
0.5080	centimeters per minute
0.0084667	centimeters per second
288.0	inches per day
12.0	inches per hour
0.200	inches per minute
0.0033333	inches per second
7,315.21440	millimeters per day
304.8006	millimeters per hour
5.080	millimeters per minute
0.084667	millimeters per second

FOOT PER MINUTE =

0.27273	miles per day
0.011364	miles per hour
0.0001893939	miles per minute
0.0000031566	miles per second
0.43891	kilometers per day
0.018288	kilometers per hour
0.0003048006	kilometers per minute

Compiled by Steven Gerolde, Gulf Oil Corporation

OIL and GAS TRADE NEWS

Inhibitor's Use Extended

Universal Oil Products Company has extended the use of Unicor, its new corrosion inhibitor, to product pipe lines. Tests have shown, the company said, that Unicor protects pipe lines and storage equipment from ordinary rusting, as well as protecting steel and admiralty equipment. The inhibitor may be injected at the refinery or in the pipe line.

Formula Changed

A new, more concentrated, formulation of "Ammate" weed and brush killer announced by the Du Pont Company contains 95 per cent of the active ingredient, ammonium sulfamate, instead of 80 per cent. The new product was planned to be used at the rate of 60 pounds per 100 gallons of water instead of 75 pounds.

Amercoat Improves Coating

A new vinyl protective coating has been developed by Amercoat Corporation. The coating can be applied at a thickness of 10 mils in a single cross-spray coat, making a heavy film that was previously obtainable only by multi-coat applications.

Bethlehem Builds "Texas Towers"

The first of several offshore radar platforms, nicknamed "Texas Towers" because of their resemblance to offshore oil drilling rigs in the Gulf of Mexico, has been launched by Bethlehem Steel at its Quincy, Massachusetts, shipyard. The stations will be located along the Atlantic Coast from New York to Newfoundland, 80 to 100 miles at sea. Each island will be of sufficient size to support electronic equipment, provide a helicopter landing, and housing for a crew.

Youngstown Builds Tin Mill

Construction of The Youngstown Sheet and Tube Company's large new tin mill facilities at Indiana Harbor is underway with the driving of foundation piles. The production of the new mill is expected to double capacity of the present electrolytic facilities. The new tin mill will require between 300 and 400 additional employees and will consist of seven buildings to be constructed on 88 acres of Youngstown property southwest of the community of Marktown, a sub-division of East Chicago.

Davison Builds Catalyst Plant

Plans for the construction of a new $4,000,000 plant for the manufacture of petroleum cracking catalysts at Curtis Bay, Maryland, was announced by the Davison Chemical Company division of W. R. Grace and Company.

The plant will manufacture the microspheroidal form of synthetic petroleum cracking catalyst, and will replace an existing plant which produces the older ground form of catalyst.

OPW Acquires Jordan Regulator

OPW Corporation, Cincinnati, Ohio, has announced its purchase of Jordan Regulator Corporation, manufacturers of pressure and temperature-regulating valves for industrial applications. The newly acquired company will be known as Jordan Corporation and will function and operate as a division of OPW.

New Plant for Robinson Orifice

A new plant site has been located in Houston, Texas, for the Robinson Orifice Fitting Company of Texas, Inc. This Texas corporation will manufacture orifice fittings and meter runs for distribution in the Mid-Continent and Gulf Coast territory.

Thermo Instruments Sells Assets

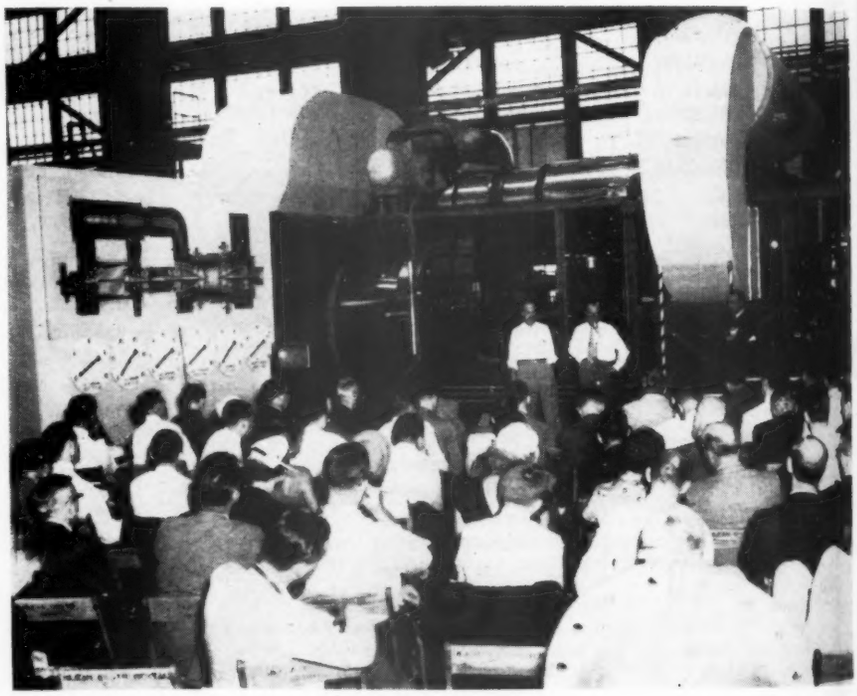
Fisher Governor Company of Marshalltown, Iowa, has acquired the assets of Thermo Instruments Company, Belmont, California, manufacturers of capacitance-probe type, liquid-level measurement-instruments. D. M. Comb, former president of Thermo, is now associated with Fisher Governor in Marshalltown.

New Oil Base, Inc. Bulk Plants

To expand distribution of Black Magic oil base drilling fluid, "Supermix" and chemical additives, Oil Base, Inc. of Compton, California, has established three new bulk storage plants in the Gulf Coast area at Alice, Texas; Lafayette, Louisiana, and Harvey, Louisiana.

Sharples Supplying Thiophene

Sharples Chemicals, Inc., a subsidiary of Pennsylvania Salt Manufacturing Company, has announced it is now supplying commercial quantities of thiophene. Commercial production of thiophene was brought on stream in June in the new plant facilities operated by Index Chemical Company (Houston, Texas), a subsidiary of Pennsalt.



Clark Bros. Show Gas Turbine Power Plant

In July, Clark Bros. Company, one of the Dresser Industries, took the wraps off something important it has been doing in collaboration with the Navy for more than a year. At its Olean, New York, plant a series of demonstrations was held to display a mobile electric power plant built for the Navy to use in emergencies. Separate demonstrations were held for the press, armed forces, government, chemical and petroleum officials, and engineers. The plant has numerous applications other than the one for which this unit was specifically designed, many in the petroleum industry.

The power plant is a complete self-contained 5500-kw unit rated at 80 F ambient temperature to an altitude of 1000 ft. The prime move is an open cycle, dual shaft, series-flow gas turbine direct driving a two pole synchronous generator.

The gas turbine consists of an axial-flow, compressor turbine with two shafts. The first (high pressure) turbine consisting of two stages drives the axial-flow compressor that supplies combustion air. The second turbine, which runs independently, drives the load generator directly at 3600 rpm.

As built for the Navy, the complete plant with auxiliaries, controls, fuel storage and handling, auxiliary-engine driven generator, and station switchgear is mounted on one rail car suited to freight or passenger train use on standard AAR gage track.

This Clark Turbo-Mobile power plant is suitable for any type of disaster, floods, fires, tornadoes, hurricanes, earthquakes, etc., as well as for industrial power in areas where none is available. Being a gas turbine, water supply is unnecessary. Also, the unit can be operated by one person.

The gas turbine used to drive the generator is equally suitable for driving centrifugal compressors in refining, gas transmission, and chemical plants.

XUM

Texas Instruments Enters Canada

Texas Instruments, Inc., Dallas, Texas, has revealed the appointment of Computing Devices of Canada, Ltd., as its exclusive Canadian agent. CDC main offices are in Ottawa, Ontario. The appointment of a Canadian agent, combined with the opening of U. S. district sales offices, will give Texas Instruments local representation over the North American continent.

Beckman Buys Liston-Becker

Beckman Instruments, Inc. has disclosed purchase of the Liston-Becker Instruments Company, Springdale, Connecticut. Liston-Becker is a manufacturer of infrared gas analyzers widely used in chemical and medical research and industrial process control. The firm also makes a specialized electronic amplifier of high sensitivity. Max D. Liston, internationally known infrared authority and founder of the company, will continue as manager of Liston-Becker operation. No change in personnel or plant location is contemplated.

Dresser Pact With Nuova-Pignone

Dresser Aktien-Gesellschaft, the European affiliate of Dresser Industries, Inc., of Dallas, Texas, has concluded an agreement with the Nuova-Pignone Company, a subsidiary of Ente Nazionale Idrocarburi (ENI) for the manufacture of Ideco drilling rigs and allied drilling equipment in Italy. The agreement was announced in Rome, Italy, at the World Petroleum Congress by officials of Dresser A. G. This new agreement is planned to help meet increasing foreign demand for the equipment manufactured by companies of the Dresser group. It will enable Italian oil and gas industries to expand more rapidly, making possible the servicing of Ideco drilling equipment now in operation more efficiently. Acceptance of an order for $2,000,000 worth of drilling equipment to be manufactured at Ideco's Beaumont, Texas, plant has also been announced. Similar equipment is to be produced by Pignone in Italy on a royalty basis in the future.

Petroleum Solvents Plant Sold

Chemical Producers Service, Inc., has acquired the plant at Port Reading, Woodbridge, New Jersey, formerly owned by Petroleum Solvents Corporation. The new owner will operate the plant as a liquid chemical storage terminal with facilities for private label packaging, drumming, canning, blending, laboratory research and formula development. Included in the plant are a tank farm, rail siding, automatic high speed packaging equipment and a versatile pipe line and pump system.

Dow Glycerine Plant in Texas

The Dow Chemical Company has said its new synthetic glycerine plant is expected to be in production at its Texas division facilities at Velasco late this summer. It will have a capacity of 36,000,000 lb per year. The plant, marking Dow's entry into glycerine manufacture, will be the second synthetic unit in the world producing on a commercial scale. Construction started about a year ago.

Jones & Laughlin Sherman Store

Jones & Laughlin Supply division has announced the opening of a new oilfield supply store at Sherman, Texas. Manager of the Sherman store is Jack A. Beaird.

BJ Service Opens Research Lab. A new and completely equipped engineering development and testing laboratory building has been opened at the Long Beach, California, headquarters of BJ Service, Inc. The new 5000-sq ft building houses engineering and development offices, a pumping process laboratory, and a wire line model shop. All are under the supervision of Matt Riordan, vice president.

Cyanamid Aids to Education

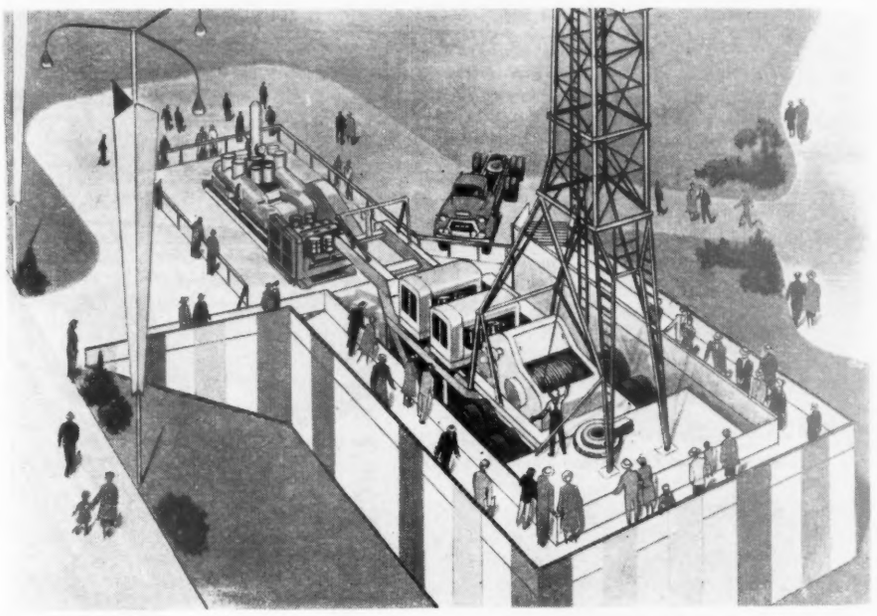
American Cyanamid Company has announced that 17 undergraduate scholarships and 14 graduate fellowships will be awarded in chemistry and chemical engineering for the academic year 1955-56. Under the company's undergraduate scholarship program, junior or senior students selected by their university or college authorities will receive $600 each for the academic year, with the school getting $300 for the unrestricted use of its chemistry or chemical engineering department. Under the fellowship program, Cyanamid will award $1500 plus full tuition and laboratory fees to graduate students in their final pre-doctoral year. Their school's chemistry or chemical engineering department will receive $300 for unrestricted use.

Gas Machinery Issued Patent

Patent No. 2,663,625 has been issued by the U. S. Patent Office to The Gas Machinery Company, Cleveland, Ohio, through inventor-assignor Paul L. Born. The patent covers the process and apparatus for converting water gas sets to high Btu oil gas. The patented arrangement is generally identified as single burner, bottom fired. It basically covers that type of oil gas installation in which an oil burner is inserted in an existing water gas generator.

McCullough Tool Opens Branch

The McCullough Tool Company has opened a new service branch in Kimball, Nebraska, complete service facilities to serve the oil industry in the area. V. J. Sanders has been appointed manager.

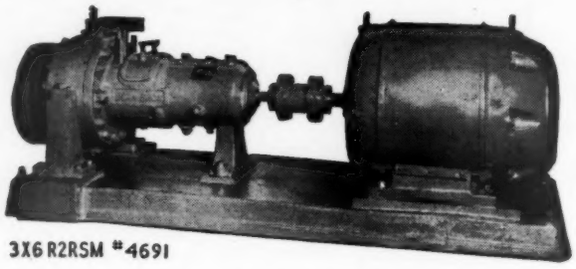


GM Powerama

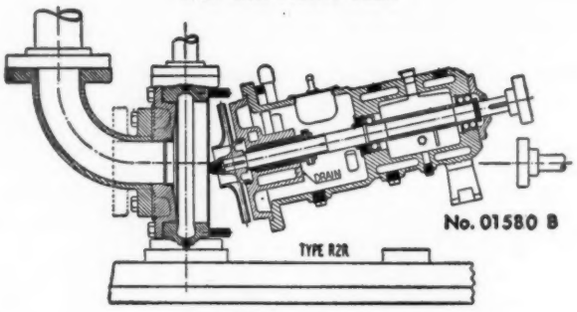
In General Motors' 26-day Powerama that opens in Chicago, Illinois, August 31, the Detroit Diesel Engine division will display a trailer-mounted rig and a mud pump powered by 6-71 and 6-110 diesel engines. A truck-mounted servicing rig and a diesel-electric rig will also be exhibited by other GM divisions. The exhibit will be one of many arranged to help celebrate GM's over-all production of 100,000,000 diesel horsepower and to show the American public the important part diesel power has today come to play in American industry. All exhibits will be of wide general interest and be open to the public without charge through September 25. The Powerama will cover a 23-acre site on Chicago's lake front adjacent to Soldier Field. Detroit Diesel's drilling rig will operate in a pre-drilled hole but pipe will be pulled and lowered once each hour to provide a realistic display. Thousands of Powerama visitors are expected to see drilling equipment in operation for the first time as a crew from the oil fields will keep the unit in operation 13 hours a day. A crew boat used in offshore drilling operations will be a part of Detroit Diesel's marine exhibit.

DEAN BROTHERS PUMPS INC.

Type R2R Centrifugal Process Pumps



Type R2R Process Pump



Type R2R Process Pump

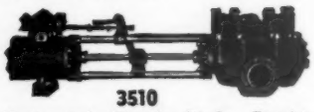
DISASSEMBLY: The Type R2R process pumps can be disassembled without disconnecting the suction and discharge piping. By first removing the spacer from the spacer type coupling, and unbolting the casing from the cradle the entire cradle and complete rotating element can be removed without disturbing the suction and discharge piping.

OPERATING RANGE: Type R2R, Heavy duty, process pumps are available in eighteen different sizes, enabling our engineers to furnish units specially designed and constructed for the particular work to be performed.
Capacities: 50 to 2000 Gallons per minute.
Heads: Up to 400'. Speeds: 900 RPM to 4000 RPM.

BUILDERS OF OUTSTANDING PUMPS SINCE 1869

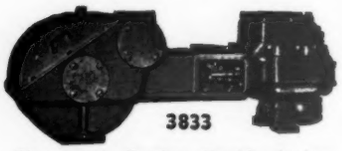
CENTRIFUGAL AND RECIPROCATING PUMPS

Close Coupled Centrifugal Pump

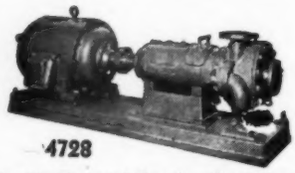


Horizontal, Single Style, Double Acting, Piston Type, Close Clearance Pump. Designed to handle volatile liquids

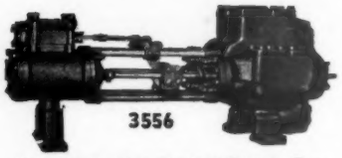
Pedestal Mounted Centrifugal Pump



Horizontal, Duplex, Double Acting Side Pot, Piston Type, Oil Bath Power Pump



Double Pedestal Bearing Centrifugal Pump



Durable Duplex Packed Piston Pattern Steam Pump, Side Pot Type

ESTABLISHED 1869

DEAN BROTHERS PUMPS INC.

INDIANAPOLIS IND.

323 W TENTH ST.

Branch Offices: NEW YORK, N. Y., HOUSTON, TEXAS

Representatives in Principal Cities

Trade News

Catalytic Completes Sun Units

Two projects recently completed by Catalytic Construction Company of Philadelphia, Pennsylvania, are the construction of two catalytic cracking units for Sun Oil Company. These projects involved construction of two Houdriflow cat cracking units with oxy-catalyst waste gas, heat-recovery steam generator systems for Sun at its Marcus Hook, Pennsylvania, and Toledo, Ohio, refineries.

The new units, each with a capacity of 30,000 bbl per day, are said to be the largest and most modern units of their type in the world. Cost of the new facilities was about $20,000,000.

Chromic Acid Plant for Diamond

A new installation for producing chromic acid has been put into operation at the Painesville, Ohio, works of the Diamond Alkali Company. Completion of this expansion project now gives this basic chemical producer two completely integrated, strategically located chromic acid plants for serving the petroleum industries.

Porter Buys Vulcan Crucible

The Vulcan Crucible Steel Company of Aliquippa, Pennsylvania, tool steel manufacturers, has been purchased by H. K. Porter Company, Inc., Pittsburgh, Pennsylvania. Vulcan Crucible becomes the twelfth Porter division. James O. Flower, Vulcan's president, will be vice president and general manager of the new Porter division.

Manostat Corporation Organized

The establishment of a new company, Manostat Corporation of New York City, has been announced by its president, Bertram M. Stone. The company will manufacture manostats for industrial use in large quantities.

Airetool Opens Dutch Plant

The Airetool Mfg. Co., Springfield, Ohio, this year is observing its silver anniversary following 25 years of continuous service in the oil refinery, power, industrial, chemical processign, and maritime industries. As a milestone marking its record of continuing growth, Airetool, has begun operation of its new overseas manufacturing plant in Vlaardingen, the Netherlands. This new plant will manufacture and stock a complete line of tube expanding, cleaning, and tube maintenance equipment.

US Steel Announces Price Raise

United States Steel Corporation has announced an increase of about 5.8 per cent in its steel prices. This amounts to less than three-eights of one per cent per pound and follows in the wake of the recent 7½ per cent increase in steel wages.

Hercules Opens New Plant

Hercules Powder Company has revealed plans to begin immediate construction of a new plant for the production of pentaerythritol (PE), representing a total investment of about $6,000,000. Completion of this plant, scheduled for late next year, will double the company's present annual capacity. Located on the site of an existing Hercules anhydrous ammonia plant at Louisiana, Missouri, the plant will have an annual production of 24,000,000 lbs of pentaerythritol and 100,000,000 lbs of formaldehyde, a basis raw material for PE.

TRADE PERSONALS

V. A. Euge

Leonard Spray

Vaughn A. Euge has been named manager of machinery sales for the California division of Emsco Manufacturing Company. Euge replaces **David A. Carnahan,** who recently resigned from the company.

Leonard Spray has been promoted to the position of assistant manager of machinery sales for Emsco. He has held the position of district manager of machinery sales in San Joaquin Valley for the past 5 years.

Harold Nutt has been elected president and general manager of the Borg & Beck division of Borg-Warner. He previously was vice president and general manager. **T. L. Knecht,** who formerly was president of the division, retired recently. Two other major executive promotions at Borg & Beck have been announced. **Clyde Bissell** has assumed the position of vice president and will continue to serve also as secretary, treasurer and controller. **Edward H. Lipke,** factory manager, now holds also the title of vice president. **Otto Janes** has been reelected assistant secretary and assistant treasurer of the division.

J. L. Helton

A. M. Cuellar

J. L. (Jimmy) Helton, who has been manager of the branch plant of The George E. Failing Company in Midland, Texas, since 1947, has been made general manager of the George E. Failing Supply Company, Ltd., of Edmonton, Alberta, Canada. Helton will replace **Harry Failing,** who recently resigned. **Don Haley** has been named manager of Failing's employee relations department at Enid, Oklahoma.

Adolph M. Cuellar has been appointed process engineer at Tellepsen Petro-Chem Constructors, a division of Tellepsen Construction Company, Houston. He is a graduate of Texas University.

Five assignment changes in the field sales and service organization of Diamond Alkali Company have been announced: **Robert R. Wood,** a member of Diamond's New York City sales staff, has been promoted to the position of special staff assistant in the sales department at Cleveland, Ohio, effective about September 1. His successaor at New York is **C. Robert Powell,** who has been transferred from Cincinnati, Ohio, where he is being succeeded by **Charles H. Gillespie** as sales representative in the Louisville, Kentucky, area. **Charles B. Kayser,** on the Cincinnati sales staff, will now represent the company at Columbus, Ohio. **Louis P. Lambros,** formerly of the central order department at Cleveland, has been named to succeed Kayser in Cincinnati. The last four changes are effective immediately.

Earle L. Kneifel has been appointed sales representative for Marsh Instrument Company in the Pittsburgh, Pennsylvania area.

C. E. Englehart

C. W. Trainer

C. W. Trainer has been appointed assistant to the area manager of the Northwest Texas area at Fort Worth for Schlumberger Well Surveying Corporation. **C. E. (Ed) Englehart** has replaced Trainer as location manager at Hobbs, New Mexico. Taking over for Englehart as location manager at Williston, North Dakota, is **Henry W. Valentine, Jr. G. O. Ellis,** field engineer at Cody, Wyoming, has been named manager of the Cody district, replacing Valentine.

C. Roger Sutton, senior metallurgist at the Argonne National Laboratory of the U. S. Atomic Energy Commission for the past five years, has joined the development and research division of The International Nickel Company, Inc., as a member of the stainless steel and heat resistant alloys section.

Albert E. Manofsky has been appointed chief engineer of Sherman Products, Inc., Detroit, Michigan.

John W. DeLind, Jr. has resigned as chairman of the board of Borg-Warner International Corporation and retired from executive duties with the company. DeLind was president of Borg-Warner International from 1946 until late in 1954.

Alfred W. Subert has been named eastern district sales manager of Bulkley, Dunton Processes, Inc., New York City.

Houdry Process Corporation, in connection with its expansion program and establishment of its new chemical division, has announced the following staff changes: **Theodore A. Burtis,** supervisor of process engineering, has become associate manager of research and development at the corporation's laboratories at Linwood, Pennsylvania. **Joseph W. Schall,** director of development, has been made assistant manager of marketing in Houdry's chemicals division. **Julius J. Cicalese,** senior process engineer, has been named supervisor of process engineering. **George W. Higginson,** assistant manager of catalyst manufacture, has been appointed assistant manager of manufacturing in the chemicals division.

The Cleveland Trencher Company, Cleveland, Ohio, has announced the promotion of **E. B. Volmar to** vice president in charge of manufacturing and the appointments of **Clifford P. Morgan** as sales manager and **David L. Raymond** as chief engineer. Works manager for the past 5 years and an employee of the company for over 15 years, Volmar has been elected to the company's board of directors. Morgan steps into the post previously filled by **John A. Penote,** now vice president in charge of sales. Raymond succeeds **Albert R. Askue,** who retired recently after serving as chief engineer for more than 15 years.

William S. Rheem II, general manager of the Rheem Manufacturing Company, has been elected to the corporation's board of directors and named a vice president of the company. The new officer is a member of the third generation of a pioneering western industrial family. His grandfather, W. S. Rheem, was president of the Standard Oil Company of California. His father, R. S. Rheem, together with the latter's two brothers, D. L. Rheem and W. K. Rheem, was a cofounder of the Rheem Manufacturing Company.

D. H. Rowe has been named as assistant sales manager of the Ridge Tool Company, Elyria, Ohio.

Franklin Supply Company, Chicago, Illinois has reelected the following officers as directors: **Jene Harper,** president; **Larry Harper,** Tulsa, Oklahoma, vice president; **Roy Wood,** vice president, and **Leland Strouse,** Denver, Colorado, vice president. **William Quan,** corporation secretary, was also elected a director, and **Albert J. Mitchell** was reelected treasurer.

H. L. Arrowood

W. H. Masterson

Hubert L. Arrowood has been appointed district sales manager with headquarters at Tulsa, Oklahoma, for Web Wilson Oil Tools, Inc. **William H. ("Bill") Masterson** has been named district sales manager at Midland, Texas, for Web Wilson.

Trade Personals

A. W. Bennett

K. W. Robbins

Alan W. Bennett has joined the Davison Chemical Company, Ltd., and has opened an office in Toronto to direct sales in Canada of Davison petroleum cracking catalysts.

Kenneth W. Robbins has been appointed by Otis Pressure Control, Inc. as service manager in Dallas, Texas, He will supervise and direct all service operations for the company.

E. S. Russey and **A. W. Rose** have been elected vice presidents of Borg-Warner Corporation. Russey is president and general manager of the Warner Gear division of Borg-Warner in Muncie, Indiana, while Rose is Pacific Coast representative of the corporation, with headquarters in Los Angeles, California. He was made the president of the division in 1950 and is also a director of Borg-Warner. Rose resigned in 1953 as vice president and assistant general manager of the Warner Gear division and then was named to represent the parent Borg-Warner Corporation's interest in financial and manufacturing circles in the Far West. At present he is on temporary assignment in Letchworth, England, where he is assisting in plans for the building and start-up of a new multi-millon-dollar Borg-Warner plant.

Karl K. Hilgendorf has been named advertising manager of Cleaver-Brooks Company, Milwaukee, Wisconsin.

Frederick C. Kroft has been appointed general superintendent of manufacturing for Haynes Stellite Company, a division of Union Carbide and Carbon Corporation.

R. L. Preston

R. B. Mallett

R. L. "Red" Preston has been appointed to head the new office of W. C. Norris, Manufacturer, Inc., in Wichita, Kansas.

R. B. Mallett has been appointed a sales and service engineer for McEvoy Company. He is in charge of the company's West-Central Texas area with headquarters in Abilene. Mallett replaces **Gil Robinson,** who has been transferred to Calgary, Alberta, Canada, as district manager.

P. E. Tobin has been appointed general sales manager of the truck division of The White Motor Company, with headquarters in Cleveland, Ohio. Tobin formerly was North Atlantic regional manager for White in New York City. He succeeds **J. N. Bauman** as top sales executive at White, the latter having just recently been elevated to the executive vice presidency of the company.

Melvin De Groote, vice president of the Tretolite Company division of the Petrolite Corporation has been awarded the Doctor of Science degree by Ohio State University. This honor was conferred recently on De Groote at commencement ceremonies at Columbus. He is vice president in charge of research development and patents. He was graduated from Ohio State with a BS in chemical engineering, later earning the professional degree of chemical engineer. De Groote holds about 750 patents, either as sole or joint inventor. Most of these are concerned with the chemical demulsification and treating of emulsified crude oils. Many of the products he developed are in daily use, all over the oil-producing world.

W. P. Schultz

Norman J. Clark

Norman J. Clark has been appointed assistant manager of the engineering and consulting department of Core Laboratories, Inc., Dallas, Texas. **W. P. Schultz** is the new senior petroleum engineer for Core.

Eion E. Dando has been named regional manager of the newly established West Coast office of Aero Service Corporation at San Francisco, California.

Reece Hatchitt is new foreign director of expanded overseas operations of Dresser Industries, Inc. He formerly handled the company's foreign legal affairs.

James W. Reed, vice president of the Cooper-Bessemer Corporation has been appointed Pacific Coast manager, in charge of the company's offices located in Los Angeles and San Francisco, California, and Seattle, Washington. **John Rogers,** who occupied this position for the past fifteen years has been appointed special representative and consultant. Reed, a vice president of the company since 1947, had been New York district manager of compressor and stationary engine sales since 1940. Two promotions in the Northwest area have also been announced. **C. R. Jones** has been appointed manager of Western Canada for Cooper-Bessemer of Canada, Ltd., and was also recently elected a vice president of this company. He had formerly been branch manager of Cooper-Bessemer's Seattle office. New branch manager in Seattle is **John McKissick.**

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To obtain more information on products advertised see page E-27

The board of directors of C. Lee Cook Company, Louisville, Kentucky, has announced the election of **Phillip W. Mettling,** formerly vice president of the company, to succeed **Fred D. Durham** as president. Durham has resigned in order to devote full attention to his duties as president and director of Dover Corporation, of which C. Lee Cook is an operating division. Mettling is a vice president and director of Dover Corporation.

Harry J. McKenzie has been named a sales representative for Neptune Meter Company. He will cover the territory of Iowa, Missouri and Kansas.

Harry J. Higgins has been named to the position of sales manager for Portland Copper & Tank Works, Inc., South Portland, Maine.

Robert W. Phillips has been appointed chief engineer of the Flex-O-Tube division of Meridan Corporation, Inkster, Michigan.

Carlton Bates has been appointed president of Solvay Process division of Allied Chemical & Dye Corporation, New York City, having been executive vice president of Solvay Process division since 1952. He succeeds **A. B. Chadwick,** who is retiring after 44 years of service, the last 5 of which were as president.

George L. Gore has been made district engineer and **Alfred Gionta** district sales engineer for Dowell, Inc., at Denver, Colorado. Gore was formerly petroleum engineer at Denver. Gionta had been Dowell's area engineer at Casper, Wyoming, until his recent promotion.

Edred J. Pennell has been appointed to the newly created position of manager of oil and gas industry sales for Owens-Corning Fiberglas Corporation, which has established a special office at 902 American Airlines Building in Tulsa, Oklahoma.

C. H. Hickman has been promoted to division manager of Mid-Continent Supply Company and will be transferred from Odessa to Witchita Falls, Texas. The North Texas district had been made a division of the organization. **G. L. Huestis of Odessa, Texas,** has been named assistant division manager of the company's West Texas-New Mexico division. Prior to his promotion, Huestis was division machinery manager of the same area.

Ben L. Aldridge has been promoted to the position of manager of the Great Bend, Kansas, office of Welex Jet Services, Inc. **Ernest M. Elbert** has been transferred to the position of sales engineer for the San Angelo, Texas, district of Welex. **Herman D. Foster Jr.,** has been named sales engineer for the Wichita Falls, Texas, district.

William L. "Bill" Hughes is the new manager of Halliburton Oil Well Cementing Company's Lubbock division. Hughes has assumed the post of the late **C. T. McGuire,** who died recently. **Joe W. Maly,** Hilliburton's assistant division manager at Oklahoma City, Oklahoma, is transferring to Denver, Colorado, to serve in the same capacity for the Rocky Mountain division. He replaces **J. W. Hall,** former assistant division manager, who is on sick leave. Taking Maley's place at Oklahoma City is **George S. Battles,** former customer contact representative for the Oklahoma division.

Arthur B. Warner has been promoted to chief engineer for Minnesota Rubber and Gasket Company, Minneapolis. The promotion marked the second advancement in eight months for Warner, who was made factory superintendent in October, 1954.

Ben E. Shelton has been transferred from Kilgore, Texas, to Wichita Falls, Texas, to head the North Texas-Southern Oklahoma district of the Happy Company. He replaces **Robert F. Snowden,** who has been moved to Cushing, Oklahoma, as field salesman for the northern Oklahoma district.

New research and design director for Continental Copper and Steel Industries Inc., New York City, is **Karl E. Fiebinger,** whose background in the field of industrial design includes positions with steel fabricators, construction companies and engineering firms, both here and abroad, as well as teaching and research. In his new capacity at CCS, Fiebinger will work out simple but efficient solutions for difficult design, manufacturing, or erection problems in marine structures and marine equipment in weldments and steel plate construction. Among Fiebinger's best-known inventions is a novel anchorage of floating wharves allowing the berthing of ships under severe conditions. Fiebinger won further renown as project engineer for the offshore defense installations built by the U. S. Navy for the U. S. Air Force off the East Coast, known as the Texas Towers Project.

The Magnet Cove Barium Corporation, Houston, Texas, has announced the following promotions in the Magcobar sales and service department: **John E. Lyons** has been named sales coordinator following the resignation of **K. L. Byerly Jr.,** who has entered private business. Lyons has been a special sales representative for Magcobar in Houston. **Arvel C. Smith,** former division sales manager with Magcobar's Mid-Continent division in Tulsa, Oklahoma, has been appointed sales administrator. He will replace **John T. Webster,** who resigned earlier this year. **R. B. Hyde Jr.,** has been named chief engineering consultant. **Jack G. Walker,** former export and industrial sales representative, has been appointed export sales manager. **R. E. Hinchliffe,** former district manager in Magcobar's Lake Charles, Louisiana, district, has been made manager of the company's Fort Worth division, succeeding **Murray C. Moffatt,** who will enter private business in North Texas.

Glenn O. Rusk has been appointed manager of the process and power division of Kerby Saunders, Inc., New York City.

Charles J. Wallace has been elected vice president and general sales manager of Houdaille-Hershey of Indiana, Inc. Lebanon, Indiana. He comes to Lebanon from the parent Houdaille-Hershey Corporation in Detroit, Michigan.

The Hammel-Dahl Company of Providence, Rhode Island, manufacturers of automatic control equipment, has announced the appointment of the MacGuire Instrument Company, 1200 Axtell Drive (Columbia), Cayce, South Carolina, as new sales and service representative in South Carolina, North Carolina and part of Virginia. **William J. MacGuire** is in active charge of the company's sales and service.

Frank F. Elliott has become president of Crane Company, Chicago, Illinois, replacing **John L. Holloway.**

Election of two new directors of Witco Chemical Company, Ltd., of London (and Manchester), England, has been announced. They are **Max A. Minnig,** executive vice president and director of sales of Witco Chemical Company, New York City, and **John A. White,** export manager of Witco Chemical Company, Ltd., London.

Rudolph Furrer, vice president of ACF Industries, Inc., formerly in charge of the nuclear energy and special products division, has been made vice president in charge of manufacturing and engineering of the parent company. He also has become president of the nuclear energy products division.

A. R. Tullos, recently promoted to division sales manager, will head the new East Texas-Gulf Coast sales division of Kobe, Inc. With Tullos in the division headquarters in Houston, Texas, is **P. M. Wilson,** district sales representative, who was transferred to Houston from Corpus Christi, Texas. In separating this area from the former Southern area sales division, Division Sales Manager **J. T. Lewis** has been transferred from Fort Worth to Midland, Texas, where he will head the newly created West Texas-New Mexico sales division. With Lewis in Midland is **S. S. McDonnold,** recently promoted to district manager. In the Fort Worth office, District Sales Representative **V. L. O'Neill,** transferred from Tulsa, Oklahoma, will be in charge of headquarters contacts in Dallas and Fort Worth. On the West Coast, **Carl Brown,** formerly manager of industrial sales in Cleveland, Ohio, has been named Los Angeles Basin district sales manager for hydraulic sales. Also working out of the Los Angeles office, but in charge of the company's coastal sales, is **W. C. Prigge,** district sales representative.

Joseph A. Scruggs, naval architect and marine engineer, has joined the staff of R. G. LeTourneau, Inc., at Longview, Texas. Scruggs has been assigned as project engineer for a mobile drilling platform for offshore oil exploration that LeTourneau is constructing for Zapata Offshore Company.

The Lane-Wells Company has opened a new branch in Willows, California, under the direction of **Carl J. Niebuhr Jr. William V. Stratton** will assist Niebuhr staff the new branch. Quarters for the office will be at 610 South Tehama Street. **L. W. Denney** has been appointed subdistrict superintendent of the Pampa subdistrict-Panhandle district, Pampa, Texas, for Lane-Wells. Prior to his appointment, Denney had been district sales engineer at Pampa since 1954. **E. C. Adock** has been named district sales engineer for the Pampa sub-district-Panhandle district. **Ivan E. Wilkerson** has also been appointed a district sales engineer for the Pampa sub-district-Panhandle district. Wilkerson has been working out of the Perry, Oklahoma, branch as a perforating operator. **Robert F. Smith,** formerly stationed at Hobbs, New Mexico, has been transferred to Houston, Texas, as district sales engineer. **Kenneth D. Frick,** formerly of Odessa, Texas, was transferred to Hobbs replacing Smith as distract sales engineer there.

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For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

(1) HEATER

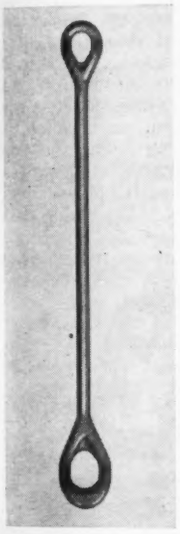
An electric oil well formation heater has been developed by the Westinghouse Electric Corporation designed to revive or improve oil production from plugged-up wells. Lowered into a well to depths of previous production, the long Corox tubular heaters raise the temperature of the oil, thereby melting the wax-like plugging material lodged within the oil bearing sand.

Westinghouse Electric Corporation.

Circle number (1) on reply card.

(2) FORGED ELEVATOR LINKS

Hi-Eye forged elevator links have been introduced by Web Wilson Oil Tools, Inc., the first sets being in use on barge rigs in the Texas Gulf Coast area by Magnolia Petroleum Company and C. G. Glasscock Drilling Company. Manufactured for use with National Supply Company's 654-F-450-ton hook-block, these Web Wilson links have inside top eye dimensions of 9½ in. by 10¾ in. The increased eye dimensions are made to provide ample clearance on the hook trunnions of these large National Hooks for proper swinging action, especially desirable when picking up and laying down pipe. Each "Hi-Eye" link has a safe capacity of 225 tons (450 tons for the set) thus providing 100 tons additional capacity over the strongest links previously made, according to the manufacturer. These links at present are manufactured in one size only.

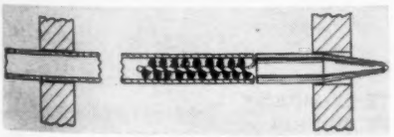


Web Wilson Oil Tools, Inc.

Circle number (2) on reply card.

(3) TUBE PILOT

Elliott Tube Pilot meets a need for replacing tubes in condensers and heat exchangers. Its use is to pilot tubes through the tube sheet and tube support plates. Pilot consists of a hardened steel



nose with a replacable nylon brush attached. The brush fits snugly in the end of the tube, centering and holding the pilot firmly in place. It is easily removed.

Elliott Company.

Circle number (3) on reply card.

(4) PORTABLE OIL BLENDER

Proportioneers has announced the development of a trailer-mounted portable fuel oil blender for bunkering ships with marine diesel fuels. This mobile blender, Model FB 2100, may be moved up and down wharfs ready for immediate blending of two base stocks in ratios of from 50-50 to 95-5 at rates up to 2100 gal per minute. Requiring no external source of power, blend ratios can be changed quickly and are automatically maintained at all rates of flow, the manufacturer says. In the event of failure of either component stream, the blender automatically stops the flow of fuel to the ship.

Proportioneers, Inc.

Circle number (4) on reply card.

(5) GAS LINE BOOSTER

A complete line of new gas-booster compressors for use in the petroleum industry has been announced. Unit consists of a gas-gathering compressor powered through a clutch and V-belt drive by a Le Roi engine. New line includes machines ranging from 10 to 300 hp. Units are equipped with automatic safety controls, allowing unattended operation and providing protection for both engine and compressor against serious damages.

Le Roi division, Westinghouse Air Brake Company.

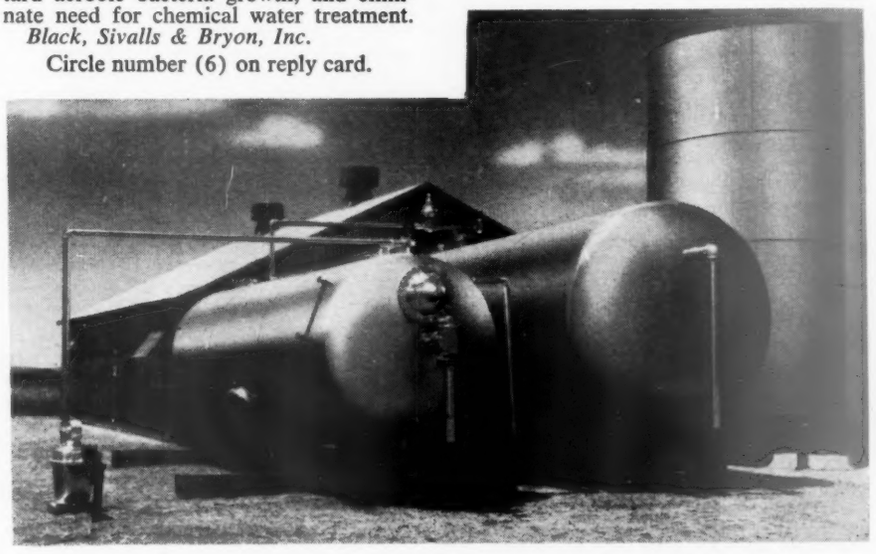
Circle number (5) on reply card.

(6) WATER CLEANER

Black, Sivalls & Bryson has introduced the Aqua-Kleener for conditioning oilfield water for sub-surface injection, offshore disposal or surface disposal. The oil traces and solids are removed from the water through a process of settling and filtering. Aqua-Kleener is a closed-type system that is designed to precipitation due to oxidation of iron, minimize corrosion, hold carbon dioxide in solution, retard aerobic bacteria growth, and eliminate need for chemical water treatment.

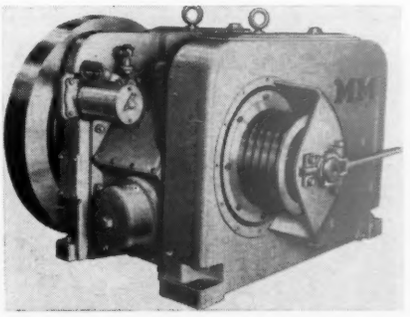
Black, Sivalls & Bryon, Inc.

Circle number (6) on reply card.



(7) "TIMELINE" ENGINE

An engine designed to run continuously for a year without service is announced by Minneapolis-Moline. The 20



hp, 2-cylinder engine is designated MM Timeline 168. Engineers designed a totally new radial cooling system, eliminating water pump, pulleys, fan, fan belt, and radiator hoses.

Minneapolis-Moline Company.

Circle number (7) on reply card.

(8) ALUMINUM SEMITRAILER

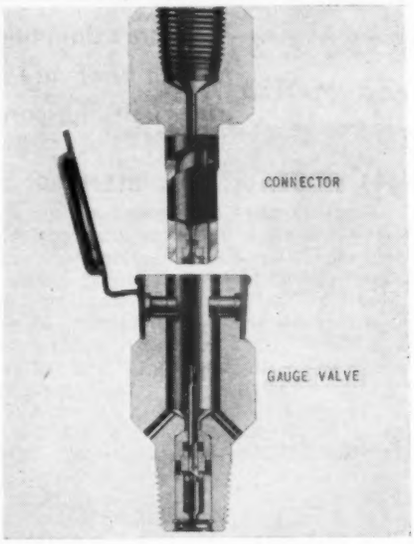
Columbian Steel Tank is now manufacturing an aluminium semitrailer that features a combination of sections of graduated diameter with two smaller sections at the front of the unit instead of the conventional cutaway. The second, or transition section, is tapered to match the different diameters of the smaller first section with the larger diameter of the rear sections. This design provides a close-coupled unit with the added feature of permitting complete jackknifing of the tractor. Columbian claims the tank will carry 10 per cent greater payload than steel semitrailers of the same gross weight.

Columbian Steel Tank Company.

Circle number (8) on reply card.

(9) GAGE CONNECTOR

Thornhill-Craver has announced the addition of a Christmas tree fitting to its line, the Christmas tree gage valve and connector. The gage valve and connector is designed to eliminate the need of



permanently installed Christmas tree gages and permits the use of a single master gage for accurate and consistent pressure readings. By eliminating the stationary Christmas tree gages it removes the hazard of the gages being broken off, stolen, tampered with, or damaged by exposure to the elements.

Unit is made of stainless steel.

Thornhill-Craver Company.

Circle number (9) on reply card.

(10) MUD EMULSIFIER

Crossett is marketing a drilling mud emulsifying agent called Seeco-Mul. This agent is a dry, powdered compound of abietic, linoleic, and oleic acids, wood tannins, and lignins. It effectively disperses the oil content of emulsion muds, the manufacturer says, which accounts for its outstanding properties of maintaining low filtration rates and good wall-building characteristics. Seeco-Mul is packaged in sturdy, moisture-proof 50-lb sacks for convenience in handling.

Crossett Chemical Company.

Circle number (10) on reply card.

(11) METAL DEACTIVATOR

Kuplex Metal Deactivator is a new Tretolite product claimed to be particularly effective in deactivating copper and copper compounds present in refinery products. Kuplex deactivates copper in other hydrocarbons as well as in gasolines.

Tretolite Div., Petrolite Corporation.

Circle number (11) on reply card.

(12) INTERMITTER GAS METER

A "Start-Stop" mechanism that drives recorder charts only during periods of actual flow has been announced by Foxboro. The device permits accurate recording of intermittent flows on gas lift and other production field operations. It is operated by a pneumatic signal (0 to 20 psi) from the gas flow intermitter; or if an intermitter is not available, it is triggered so that the drive starts when the recording pen leaves zero flow and stops when the pen returns to zero.

The Foxboro Company.

Circle number (12) on reply card.

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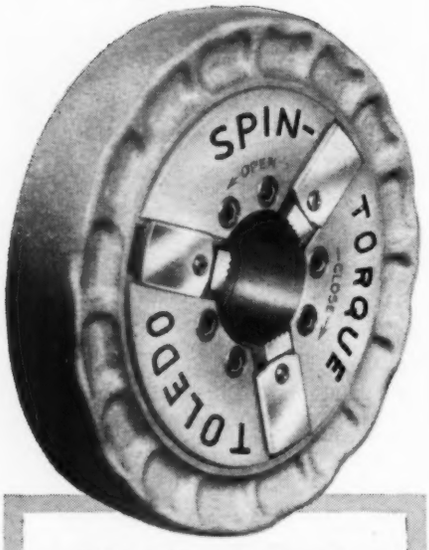
TOLEDO
SPIN TORQUE
CHUCK



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TEMPERATURE RECORDERS

(13) CABLE TENSIOMETER

An improved instrument for electrically measuring tension in wire rope, the Baldwin SR-4 Tensiometer, may be attached anywhere on a tensioned cable by screw clamps at each end of the instrument. Tension is measured by the force exerted on an adjustable pin that deflects the cable midway between the clamps. Force measurements are transmitted from strain gages in the tensiometer to a central indicator or recording instrument. The tensiometer is designed for loads up to 5000 lb on cables up to ½ in. in diameter but can be made for other sizes and types of cables.

Baldwin-Lima-Hamilton Corporation.

Circle number (13) on reply card.

(14) TUBING CUTTER

Houston Engineers, Inc., has developed an inside tubing cutter that will wash down, cut, and recover the cut section in a single run, called the H-E Hydraulic Inside Cutter. Tool travels within the tubing, drilling and washing as it goes, and makes its cut at a point below the obstruction. The fish is engaged before the cut is made, and upward strain on the cutter gives positive indication of severance. Fish is then recovered on the back trip.

Houston Engineers, Inc.

Circle number (14) on reply card.

(15) PLASTIC PIPE FITTINGS

A complete line of plastic pipe fittings is now available for use with Reflin fiberglass, reinforced-thermosetting, corrosion-service plastic pipe. Connections may be made quickly and positively without tools by using slip-sleeve couplings or threaded-sleeve adapters, the manufacturer says. Couplings or adapters are cemented in place to form a positive, leak-proof joint as strong as the pipe itself. Fittings are available in 4, 6, 8, 10, and 12-in. OD sizes.

Reflin Company.

Circle number (15) on reply card.

(17) MULTI-PURPOSE VALVE LUBRICANT

A multi-purpose valve lubricant with an unusually wide field of applications and record temperature range, Rockwell-Nordstrom No. 555, has been introduced. It offers good metal-wetting qualities at both sub-zero and highly elevated temperatures and is unusually resistant to mixtures of hydrocarbons in both acid and alkaline solutions.

Rockwell Manufacturing Company.

Circle number (17) on reply card.

(18) BARGE OIL HOSE

Thermoid has designed a lightweight barge oil hose for handling gasoline and oil in river and lake operations. This smooth bore hose is made in five sizes. The 3, 4 and 6-in. (ID) sizes are available in 50 ft lengths. The 8 and 10-in. (ID) sizes are made in 35 ft lengths. Four of round, steel reinforcing wire permit to six plies of strong fabric plus a helix positive or negative pressures of up to 100 psi. Both the tube and cover are of neoprene to resist attack from petroleum products. Weights per foot range from 4.5 lb for the 3 in. and up to 17.6 for the 10 in.

The Thermoid Company.

Circle number (18) on reply card.

(19) TATTLE-TALE SWITCH

On installations where more than one safety switch is used, it is often difficult to determine the cause of the shut down. To assist the mechanic in locating the trouble, the Frank W. Murphy Company has introduced an indicating switch, 101-PH, for use on pumping units and other installations where automatic shut-down equipment is used. Switch includes relay for shorting out the magneto to shut-down engine. Indication is provided by the push button that extends if switch is tripped. 101-PH switches can be supplied on panels with as many tattle-tale switches as required or in individual units.

Frank W. Murphy Company.

Circle number (19) on reply card.

(20) BELLOWS RELIEF VALVE

Model JB Protecto-Seal Bellows Relief Valve has been introduced by Crosby Steam Gage & Valve Company. It is designed primarily for use on services where protection against corrosion, fouling of working parts, and low back pressure surges is required. The Protecto-Seal Bellows Relief Valve (patent applied for) shields the bellows from adverse turbulent effects from the flowing media, preventing premature failure of the bellows due to fatigue. Effective area of the valve seating surface is essentially balanced to nullify the effect of variable and constant back pressure on its performance. All moving parts of the valve are guided and held in perfect alignment by a single member. The floating disc is loaded at the lowest point possible to insure alignment stability and seat tightness.

Crosby Steam Gage & Valve Company.

Circle number (20) on reply cord.

(21) LEAK REPAIR PLUG

Leak repair plugs for making permanent or emergency repairs in gas lines, tanks, and boilers are now marketed by R. H. Baker & Company. Made in a variety of sizes of special heat-treated alloy steel, these are plugs designed to take the strain of thread cutting themselves into a hole to seal the break effectively. For permanent repair or to reinforce weak metal, plugs may be welded.

R. H. Baker & Company, Inc.

Circle number (21) on reply card.

(22) VIBRATION MONITOR

Beta Model 4 Vibraswitch is used to protect pipe line pump motors, large gas and diesel engines, compressors, and other heavy rotating equipment against damage in the event of a failing bearing or otner malfunction causing an increase in vibration. The pickup is in an explosion-proof housing for mounting on the protected equipment and monitor control unit may be mounted up to 200 ft away. Time delay relays prevent shutdowns on starting or from transient disturbances. Typical sensitivity range is 0.2 to 20 mils double amplitude at 1800 or 3600 rpm.

The Beta Corporation.

Circle number (22) on reply card.

(23) DRILL PIPE PROTECTOR

The PB Division of Byron Jackson Company now offers the "Safe-Lok" Protector that can be installed or removed by regular drilling crews using only a simple wrench. The locking parts of the drill pipe protector are permanently incorporated in the protector. "Safe-Lok" protectors are available in a range of sizes and lengths for drill pipe sizes from 3½ in. to 5½ in.

Byron Jackson Company.

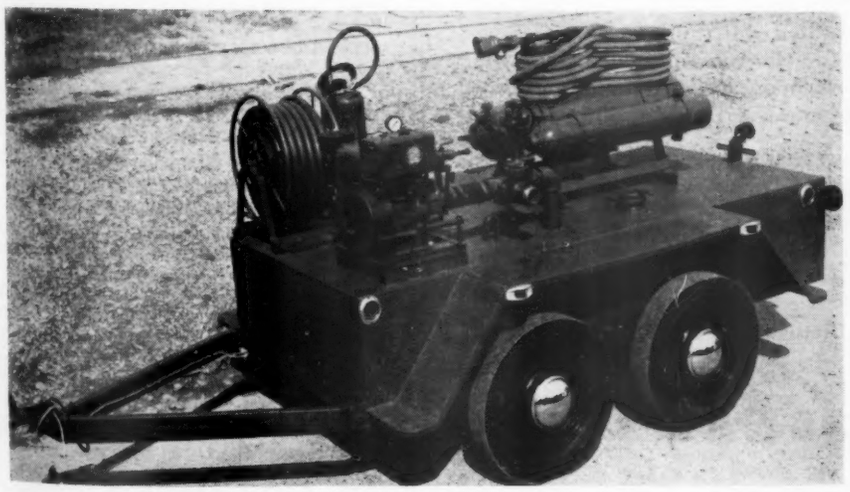
Circle number (23) on reply card.

(24) 'TUFFY NUFF'

"Tuffy Nuff" D & B Ductile Iron Liners made of ductile iron, the two-in-one metal claimed to have the strength and ductility of steel and the low cost of iron, have been developed to solve oil industry pumping problems. According to the manufacturer, liners are tough enough to increase liner life two to five times. The ductile iron used possesses the toughness of steel and the wearing qualities of cast iron.

D & B Division, Emsco Manufacturing Company.

Circle number (24) on reply card.



(16) FIREFIGHTERS

Henry H. Paris Distributor has placed on the market a completely self-contained fire-fighting trailer. Unit is 4 ft by 8 ft by 18 in., carries 360 gal. of water, and has low center of gravity making it practically impossible for the trailer to overturn. Mounted atop the trailer body are a high-volume, high-pressure pump; hose reel; 100 ft of 1 in. high pressure hose; 150 lb dry chemical tank, with 50 ft of hose; 30 lb-hand extinguisher; valves, and all controls. Thirty feet of 2½ in. suction hose is carried in a special compartment at the rear of the trailer.

Henry H. Paris Distributor, Inc.

Circle number (16) on reply card.

(25) PORTABLE EVAPORATOR

A portable, laboratory model Turba-Film Evaporator for pilot plant study of the unit operations of evaporation, single-step distillation, deodorization, heating, cooling, or other heat treatment is now available. Evaporator uses Rodney Hunt's unique agitated film method and is provided with a heat transfer area of one square foot. Unit is designed for use of heating mediums up to 250 psi and 700 F. Steam jacket of the evaporator is also baffled for use of hot oil as heat transfer medium. Condenser is a vapor-in-tube unit of 316 stainless steel in contact with process vapor. Variable speed drive permits rotor speed changes as required for technical studies. It can be supplied as an individual unit with stand or with auxiliary condensing equipment, or as a complete packaged plant including vacuum equipment, feed pumps, discharge pumps, and instruments as required.

Rodney Hunt Machine Company.

Circle number (25) on reply card.

(26) MICROWAVE METER

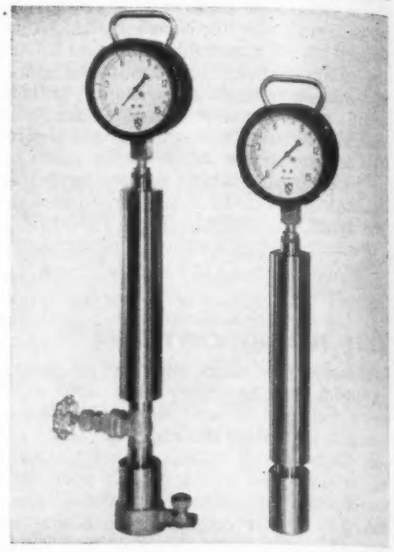
Direct, automatic readings of microwave power levels from 1/10 to 10 mw now are available in the Model 430C microwave power meter marketed by Hewlett-Packard. It gives power readings direct in decibles or milliwatts and eliminates computation and adjustment during measuring. Either pulsed or CW power may be measured on either waveguide or coaxial systems. Operation of the instrument is entirely automatic, and it may be used with a wide variety of bolometer mounts.

Hewlett-Packard Company.

Circle number (26) on reply card.

(27) REID PRESSURE BOMBS

Precision Scientific Company has redesigned the Reid Vapor Pressure Bombs used for ASTM Methods D 323 "Test for Vapor Pressure of Petroleum Products



(Reid Method)" and D 1267 "Test for Vapor Pressure of Liquefied Petroleum Gases." New bombs feature easier assembly and disassembly, requiring no wrenches or other tools. A bleeder valve and adapter assembly is available for use with the bomb when testing LPG by the ASTM Method.

Precision Scientific Company.

Circle number (27) on reply card.

(28) THREAD COMPOUND

Jet-Lube "Thick-or-Thin" Sealing Compound for use on line pipe threads, flanges, and pressure gaskets is insoluble in petroleum oil, gas, and water. It can be thickened to stiff consistency for application as a flange and gasket paste by adding water or can be thinned with solvent for brush or spray application. Special chemically inert filler is combined with pure metallic lead and graphite to provide a matrix in thread grooves and between gasket faces to form a slightly malleable seal. A flexible but tough, polymerized film forms upon exposure.

Jet-Lube, Inc.

Circle number (28) on reply card.

(29) SMALL DRILLING SWIVEL

Production of a new type N-24 swivel for drilling to depths up to 4000 ft has been announced by The National Supply Company. Swivel has been designed to include the following features: A lowered center of gravity for greater stability in handling; a quick-seal hose-connection assembly, and a light-weight Uniflex wash-pipe, packing-box assembly that can be handled by one man and installed without removing the gooseneck or hose connection.

The National Supply Company.

Circle number (29) on reply card.

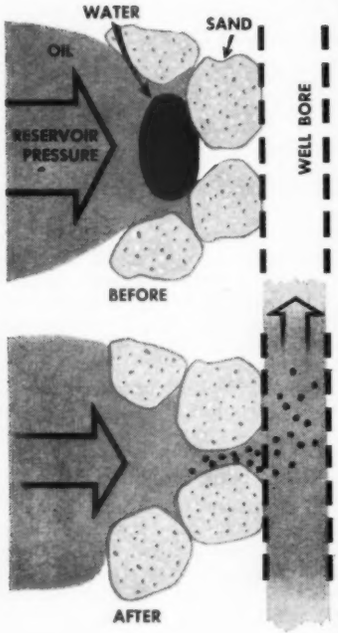
(30) ATOM SMASHER

A heavy-particle generator and accelerator instrument, McCullough Neutron Generator, has been developed by McCullough Tool for use with a scintillation spectrometer in determining the mineral content of the earth formations surrounding the well bore.

The McCullough Tool Company.

Circle number (30) on reply card.

Improve Oil Production with PR-277



PR-277 removes water blocks by lowering the oil-water interfacial tension which causes the water droplets to lose their rigidity and allows the oil to flow.

a surface-active agent for use in water-block removal

Aquaness has developed PR-277 to stimulate well production by removing water blocks and solving problems caused by water.

Recently, seven poor producing wells were treated with PR-277. Only 196 gallons of this chemical were used, resulting in a total *daily* oil production increase of 165 barrels.

The added daily production paid for the total chemical cost in slightly over two days' production at the increased production rate.

OTHER AQUANESS PRODUCTS INCLUDE:

- Chemical compounds for petroleum dehydrating and desalting
- Nonionic surface active chemicals
- Corrosion inhibitors
- Scale compounds
- Bactericides

Aquaness Corporation

2005 Quitman, Houston, Texas • Telephone CA 8-6697

Gentlemen: Please send me additional information on PR-277.

Name_____ Firm _____

PE-3

Address_____ City_____ State_____

(31) ONE-SHOT VISCOMETER

Gardner One-Shot Viscometer is a disposible viscometer designed for fluid viscosity measurements in the field and laboratory. It consists of a metal stand, paper orfice, and receiver cups. Orfice

cups are carefully constructed so there is little variation in their volume. Size of orfice is held constant with respect to internal diameter and length. Since all parts coming in contact with fluid are disposible, use eliminates clean up time.

Gardner Laboratory, Inc.

Circle number (31) on reply card.

(32) TWO-ZONE PUMP

A "two-zone" pump utilizing primarily Standard API parts and requiring only three special components, has been developed by Axelson. Traveling-valve pumps of the sure seal type are used in the assembly. Two "two-zone" pump is normally used in a crossover-flow type dual completion but can be adapted to multiple-tubing type installations. Pumps and seating mandrels are run in the tubing and positioned with the rod string. Use of standard parts provides wide selection of components to meet varied well requirements.

Axelson Manufacturing Company.

Circle number (32) on reply card.

(33) FITTINGS-FLANGES

A complete line of solvent-welding pipe fittings and flanges of injection-molded, unplasticized polyvinyl chloride has been introduced by Tube Turns Plastics. Line now includes 90 deg and 45 deg elbows, tees, unions, couplings, caps, reducing bushings, and flanges. Solvent-welding fittings permit fast, easy installations to be made with a minimum of tools.

Tube Turns Plastics, Inc.

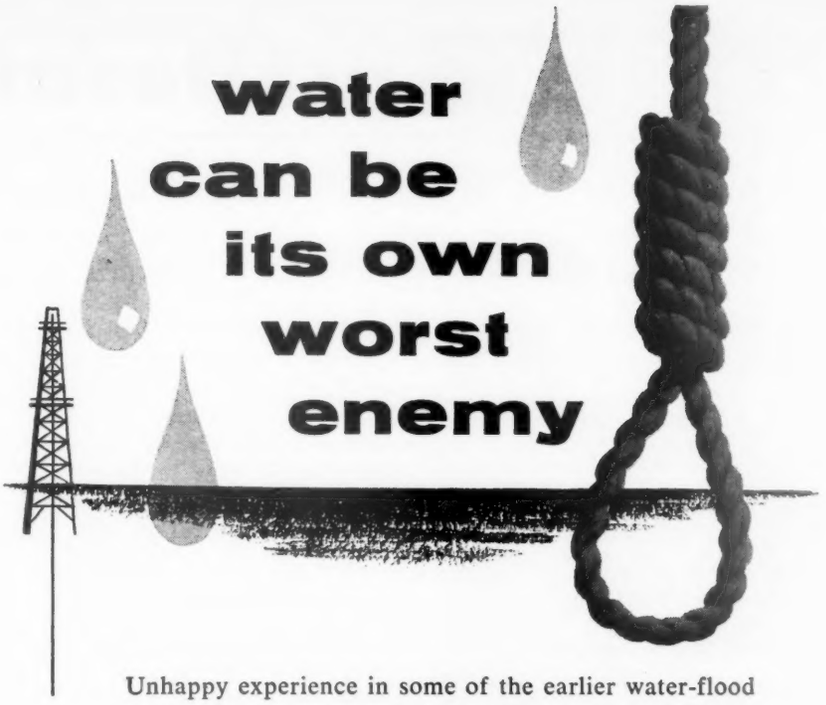
Circle number (33) on reply card.

(34) GAS FILLED MOTOR

A line of totally enclosed, inert gas-filled motors in a wide range of ratings for safe operation in hazardous gas-contaminated areas has been announced by Allis-Chalmers. Enclosures utilize air-to-water surface heat exchangers to remove the heat of motor losses. Under positive pressure, the non-explosive gas inside the motor keeps out volatile ambient gases that could cause an explosion. A gas pressurizing manifold is used to maintain positive pressure within the housing. Other special equipment includes explosion-proof instrumentation for temperature detection, liquid-level alarm and water-flow metering.

Allis-Chalmers Manufacturing Company.

Circle number (34) on reply card.



Unhappy experience in some of the earlier water-flood projects has demonstrated that the injection water itself may be the very thing which defeats the project . . .because it can carry into the formation the precipitants, algae and bacteria which have been established as major causes of formation-plugging.

But, today, many of the advanced water-flood projects now in operation have no trouble at all from this source. They have installed modern diatomite filtration systems and, using Dicalite filteraids, are filtering out completely the microscopic water-borne solids which could slow or halt the water drive. That's because Dicalite filtration is so "sharp" that it traps unwanted solids even down in the sub-micron size range: up to 95% of all bacteria can be removed by Dicalite filtration.

Diatomite filtration systems take up little room – about 1/5 that required for the older, less-efficient sand filters – and their installation costs are comparatively low. In addition, diatomite filter systems can be moved to another location when and if desired; in fact, some of the newer systems are completely unitized for easy hauling.

If you'd like your water-flood project to continue at its designed input pressure, instead of watching pump pressures continue to climb, day by day—if you'd like to free your mind of at least one problem in a re-pressuring project – investigate the advantages of Dicalite filtration as used and proved by other operators. A new Dicalite Bulletin, now in preparation, covers the subject in detail . . . send in your name and we'll send you your copy as soon as it's printed.

DEPENDABLE SERVICE TO INDUSTRY 25 YEARS Dicalite 1930-1955

Dependable GLC GREAT LAKES Dicalite® DIATOMACEOUS MATERIALS

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NEW oil and gas Literature

- **Brochures**
- **Bulletins**
- **Catalogs**

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

(35) "ELECTRIFUGAL"

Model C-3 supporting adapter "Electrifugal" pumps are described in a bulletin by Allis-Chalmers Manufacturing Company. Units are available in capacities to 2500 gpm, heads to 400 ft and temperatures to 250 F. Pumps described are those having a casing with removable suction cover and those having a casing with suction and discharge nozzles in one piece.

Allis-Chalmers Manufacturing Company.

Circle number (35) on reply card.

(36) TEFLON PRODUCTS

Chemical and Power Products offers new bulletins, No. CP552, CP553, and CP554, covering Teflon packings, gaskets, special parts and stock.

Chemical and Power Products, Inc.

Circle number (36) on reply card.

(37) OIC GATE VALVES

Two new brochures are available on OIC iron body and union bonnet bronze gate valves. Included are engineering data for the various valve sizes.

Ohio Injector Company.

Circle number (37) on reply card.

(38) AUTOMATIC TELETYPE

"Automatic Teletypewriter System for Gas Lines" is the title of a bulletin released by Berkeley Division of Beckman Instruments.

Beckman Instruments, Inc.

Circle number (38) on reply card.

(39) OIL FILTERS

Three eight-page equipment bulletins have just been issued by Houdaille-Hershey of Indiana. They tell about the company's line of Honan-Crane oil filters.

Houdaille-Hershey of Indiana, Inc.

Circle number (39) on reply card.

(40) DIAMOND DRILL BITS

A catalog on its line of diamond drill bits has been issued by Diamond Tool Research Company.

Diamond Tool Reserach Company, Inc.

Circle number (40) on reply card.

(41) BRONZE GLOBE VALVE

An illustrated, four-page circular describing the new LQ600 valve, said to be the first bronze globe valve with Brinalloy seats and discs, has been prepared by the Lunkenheimer Company. Designed and engineered by Lunkenheimer, the LQ600 valve is remarkably resistant to wear and corrosion, according to the company. The seat-and-disc alloy (Brinalloy), developed by Lukenheimer, is claimed to outlast case-hardened stainless steel extending 1000 Brinell.

The Lunkenheimer Company.

Circle number (41) on reply card.

(42) FLARELESS TUBE FITTING

Parker has announced in a new catalog a flareless-type tube fitting, designed especially for copper instrumentation lines and designated the "Intru-lok." The new fitting features easy, "in-true" tube entry and quick connection without disassembly of the fitting.

Parker Appliance Company.

Circle number (42) on reply card.

(43) INFRARED SPECTROPHOTOMETER

A four-page bulletin describing Beckman's automatic infrared spectrophotometer is just off the press. The Model IR-2A described is designed to be a high-performance, low-cost instrument suited to both research and quantitative analysis.

Beckman Division, Beckman Inustruments, Inc.

Circle number (43) on reply card.

(44) CENTRIFUGAL WET DUST COLLECTOR

A four-page bulletin has been announced by Pangborn describing its type "CW-1" centrifugal wet dust collector. The illustrated bulletin gives complete data on the Pangborn counter-current, wet collector of tower construction.

The Pangborn Corporation.

Circle number (44) on reply card.

(45) CONTROLLED VOLUME PUMPS

Milton Roy Company has announced a bulletin describing Controlled-Volume Pump Model H-20 designed for accurate chemical feed at low cost. Information includes data on simplex and duplex models, capacities, pressures, materials of construction, and mounting dimensions.

Milton Roy Company.

Circle number (45) on reply card.

(46) FINNED TUBING

A bulletin on finned tubing has just been published by Griscom-Russell. The tubing described in this bulletin is the G-R G-Fin tube with longitudinal fins, said to have six to eight times the exterior surface of the same length of bare tubes. Therefore, when used for heat transfer between two fluids of dissimilar heat transfer rates, these finned tubes permit the use of heat exchangers that are smaller than with bare tube units.

The Griscom-Russell Company.

Circle number (46) on reply card.

(47) AIR-LINE LUBRICATORS

An illustrated bulletin on Air-Line Lubricators is now available from Ingersoll-Rand. The lubricators described in this bulletin are made in sizes for use with the smallest hand-held air tools to the largest quarry-type drills.

Ingersoll-Rand Company.

Circle number (47) on reply card.

(48) TANK GAGES

An eight-page bulletin describing a line of remote reading industrial liquid depth gages is now available from Liquidepth Indicators.

Liquidepth Indicators, Inc.

Circle number (48) on reply card.

(49) PERMANENT COMPLETIONS

"ITCO-Equipped Lubricator for Permanent Completions" is a 12-page brochure featuring specialty items of the Bowen Company of Texas. Line wipers, wire line control head, wire line blowout preventer, and jarring tools are described and illustrated in detail.

Bowen Co. of Texas, Inc.

Circle number (49) on reply card.

(50) WATER-BLOCK REMOVAL

"Chemical Reagents for Oil Well Stimulation" is the title of a bulletin that describes water-block removal with Aquaness PR-277. A surface-active agent, it removes water blocks by lowering the oil-water interfacial tension, which causes the water droplets to lose their rigidity and allows the oil to flow.

Aquaness Corporation.

Circle number (50) on reply card.

(51) PROTECTIVE COATINGS

A 19-page report on "Comparative Properties of Protective Coatings" has been made available by Atlas Mineral Products. The report contains information on 14 types of coatings used widely to protect equipment, walls, beams, and ceilings in plants where fumes and industrial atmospheres cause corrosion.

The Atlas Mineral Products Company.

Circle number (51) on reply card.

(52) GLYCOLS

A 60-page book describing glycols has been published by Carbide and Carbon Chemicals. The twelve commercial glycols and triols sold by the company are discussed in detail.

Carbide and Carbon Chemical Company.

Circle number (52) on reply card.

(53) PUMPING UNITS

Crank counterbalanced pumping units are described in four, 8-page bulletins issued by National Supply. These bulletins show types E-9, E-11, E-13, and E-15 with latest design improvements.

The National Supply Company.

Circle number (53) on reply card.

(54) DIESEL-POWER UNIT

A booklet describing the UD-525 diesel-power unit has been published by International Harvester. This power unit develops 115 hp at 1800 rpm.

International Harvester Company.

Circle number (54) on reply card.

(55) VAPOR PRESSURE CHARTS

A 20-page booklet entitled "Vapor Pressure Charts for Petroleum Hydrocarbons" has been published by Esso Research and Engineering Company. Included are new vapor pressure charts and tables developed by the company for petroleum hydrocarbons.

Esso Research and Engineering Company.

Circle number (55) on reply card.

(56) CASH CONTROLS

A wide range of Cash Standard pressure, hydraulic, temperature, process, and combustion controls is described in a four-page bulletin published by the manufacturer, A. W. Cash.

A. W. Cash Company.

Circle number (56) on reply card.

(57) OIL HOSE

A data sheet on tank, fuel oil, and butane-propane hose has been published by B. F. Goodrich. Sheet describes, illustrates, and gives specifications and recommended uses for the BFG line of hose products.

The B. F. Goodrich Company.

Circle number (57) on reply card.

(58) HYPALON

A new publication for maintenance, operating, and design engineers will be issued periodically by Du Pont. The first issue briefly describes "Hypalon" chemical rubber and details some of the outstanding attributes of this versatile new elastomer.

E. I. du Pont de Nemours & Company.

Circle number (58) on reply card.

(59) PORTABLE TANKS

Huge collapsible storage tanks for storing bulk liquids as an emergency or temporary measure are now in production for commercial use. Portable tanks are being manufactured in 900, 3000 and 10,000-gal sizes, with larger and intermediate sizes available on special order. A 12-page illustrated brochure is available that gives complete information on the construction and applications.

Aviation Products Division, Goodyear Tire & Rubber Company.

Circle number (59) on reply card.

(60) STEEL-BELT CONVEYORS

A 48-page, hard cover book giving extensive engineering and application information on Sandvik steel-belt conveyors is now available. Illustrated with both photographs and drawings, the book is a thorough presentation on conveying via a solid steel band. It describes the basic features of the conveyor and the steel belt and gives details on characteristics, capacities, adaptations, and design.

Sandvik Steel, Inc.

Circle number (60) on reply card.

(61) TWO-STAGE COMPRESSOR

Allis-Chalmers two-stage, sliding-vane type compressors for shop air, gas handling, and drilling are described in a bulletin released by the company.

The publication carries a table of ratings for the compressor and a table of outline dimensions for the units.

Allis-Chalmers Manufacturing Company.

Circle number (61) on reply card.

(62) SIDE-WALL CORING

Schlumberger has published an eight-page booklet with color photographs on side-wall coring. All oil producing areas of the U. S. are represented in the life-size pictures of typical cores taken with the Schlumberger side-wall coring tool, according to the manufacturer.

Schlumberger Well Surveying Corporation.

Circle number (62) on reply card.

(63) DIESEL ENGINES

Worthington has issued a new bulletin on diesel engines that presents information on construction details, applications and latest design features.

Worthington Corporation.

Circle number (63) on reply card.

(64) PORTABLE COMPRESSORS

A 12-page catalog just issued by Le Roi Division pictures all of the 40 models of portable-type compressors available. The quick reference chart shows the contractor the capacities, engine types, and mountings available.

Le Roi Division, Westinghouse Air Brake Company.

Circle number (64) on reply card.

(65) NEEDLE BEARINGS

A catalog presenting design, application, and use data for five types of needle bearings is being distributed by Torrington. The illustrated catalog comprises in effect a bearings short course.

The Torrington Company.

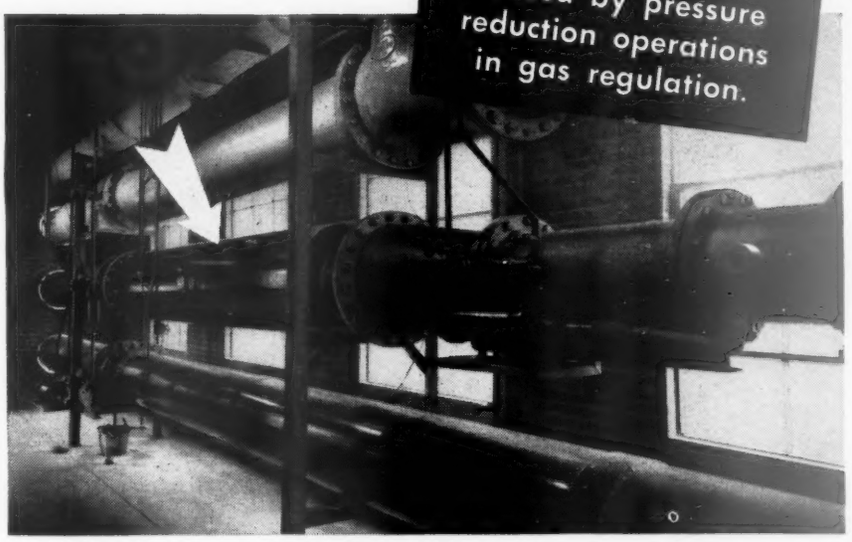
Circle number (65) on reply card.

95% to 99%

noise energy eliminated in Gas Regulation

BURGESS-MANNING PRS SILENCERS

are designed to stop nerve-wracking noise caused by pressure reduction operations in gas regulation.



The PRS Silencer in the photograph is installed in the gas regulator system of the gas mixing plant at the Lehigh Valley Gas Division, United Gas Improvement Company, Bethlehem, Pennsylvania. This regulator reduces natural gas pressures from 45 psig. to approximately 2 psig. Sound Surveys at this installation prove the PRS Silencer—

- Removes 95% to 99% of the noise energy.
- Reduces noise levels at critical outside locations by 18 to 25 db.
- Eliminates the need for expensive pipe lagging.

With PRS Silencers you *gain* in *two big* ways—

1. Pressure reduction silencing with predictable results.
2. Initial savings in installation time and material.

. . . PRS Silencers do not restrict line flow.

They can be designed for any pressure range.

They require no major modification in practice.

We offer you a specialized experience and engineering service

Ask for your free copy of engineering reports

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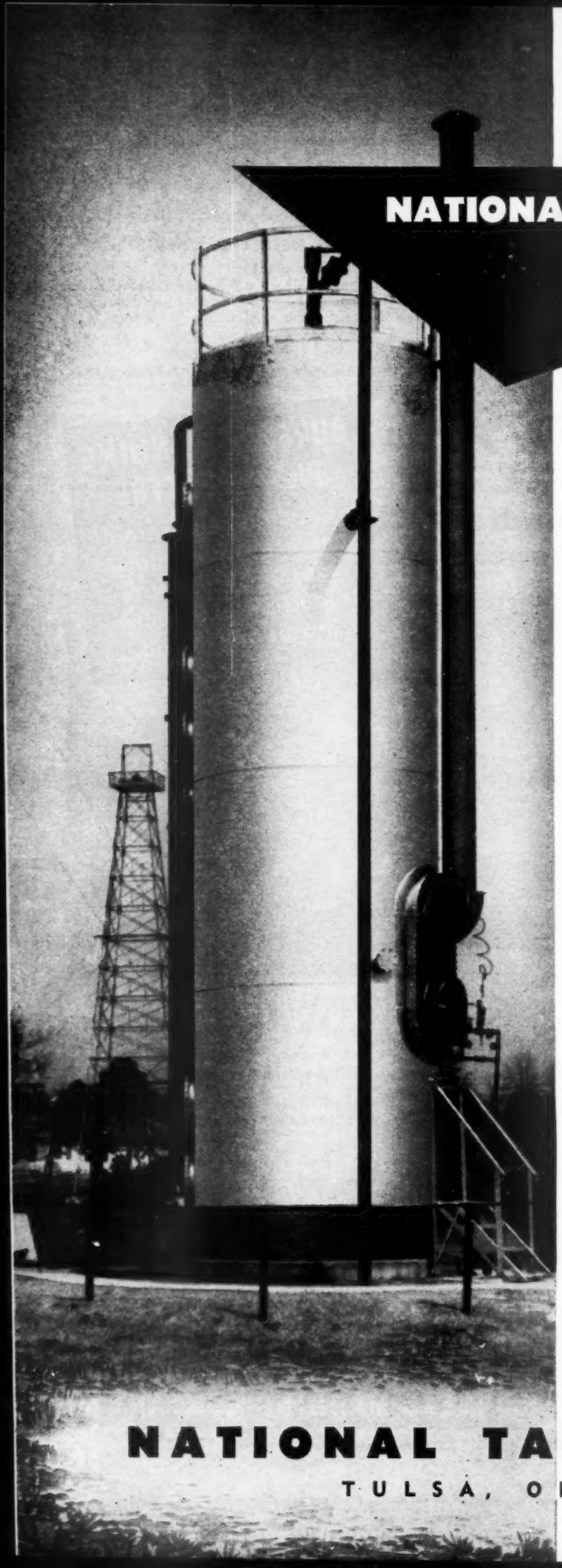

NATIONAL ICP TREATER . . .

SAVES
$731.64 PER MONTH

Inter-Office Correspondence

To: [redacted] Date: April [redacted]

Subject: National ICP Treater
installed on our [redacted] Lease.

Dear Bud:

We thought you might be interested to know of the results obtained from the installation of the ICP Treater on our [redacted] Lease last September.

In figuring the amount of gas purchased for this lease, taking months comparable in weather conditions, six months before and six months after the installation, we find that in the preceding six months we bought gas in the amount of $1,298.99 and in the succeeding six months we purchased gas in the amount of $599.47 a total saving for six months of approximately $699.47 or $133.00 per month.

Before installing this Treater it was necessary that we clean ten tanks per month, losing approximately twenty barrels of oil each time. This would amount to 200 barrels per month or approximately $486.00 per month. This Treater has now been in service approximately eight months and we have not cleaned a single tank.

In addition to the gas and tank cleaning saving we also raised the gravity of the oil an average of 1°, which raised the price of the oil .02¢ per barrel. As this lease averaged 5,632 barrels of oil per month after installation of the Treater the amount gained on raising the gravity amounted to $112.64 per month.

We figure the total savings as follows:

$133.00 per month saving on gas.
$486.00 worth of oil saved each month.
$112.64 more per month for increased gravity.
$731.64 Total saving each month.

The first six months after installing this Treater we had saved $4,395.84. As the Treater cost $3,439.26, at the expiration of six months the Treater was paid for with $956.58 left over as profit.

Respectfully yours,

[redacted]

It's a National

NATIONAL TANK COMPANY

TULSA, OKLAHOMA

XUM

In average wells with mild abrasion and medium corrosion

"Oilwell" NICKEL-IRON Subsurface Pumps give longer-than-average service

"Oilwell" NICKEL-IRON Pump Barrels are made from solid castings of fine-grained, nickel-alloy cast iron. Nickel strengthens and improves the inherent resistance of cast iron to corrosion, wear and impact.

By rifle boring these castings, a dense, tough, inside working surface is secured that can be honed and finished with extreme precision. Tolerances are so exact that factory matching of plunger components is unnecessary and out-of-stock, metal-to-metal plunger replacements fit perfectly.

NICKEL-IRON is available in both rod and tubing pumps, as well as working barrels for flexible plungers. Their low cost and their exceptional service records from Pennsylvania clear to the Rocky Mountains, prove them to be the most economical pumps you can buy for average well conditions.

OIL WELL SUPPLY
DIVISION
UNITED STATES STEEL CORPORATION

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Export Office—
30 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.

Area Offices—
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CASPER, WYOMING.....COLUMBUS, O.
DALLAS, TEXAS.....HOUSTON, TEXAS
TULSA, OKLA.....LOS ANGELES, CALIF.

Branches Serving All Oil Fields

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"OILWELL"

TRADE MARK

UNITED STATES STEEL

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Indexed by Industrial Arts Index and The Engineering Index, Inc.

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LETTERS

Thanks for 'Gas' Views

I have just read your editorial on the natural gas question and it is indeed interesting and convincing. We must continue our effort to get this story across to as many people as possible and the valuable support of your fine magazine . . . is a real contribution and we appreciate it.

G. A. Mabry

Humble Oil & Refining Company
Houston, Texas

Engineer Shortage

Editor's note: This letter that has come to our attention is of such value, and is so exemplary of an awakening by those within the oil industry to the need for engineers and better-trained personnel, we feel that it should be passed on to The Petroleum Engineer readers.

Organizations and companies within the industry are acting to eliminate this trained manpower shortage. For a report on what is being done by the American Association of Oilwell Drilling Contractors in this field, read the article forthcoming in the October issue.

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Dr. Alan T. Waterman,
Director,
National Science Foundation,
Washington, D. C.

Dear Dr. Waterman:

I was much interested in your report (INS, Washington, D. C., July 23) in reference to the drastic shortage of scientists and engineers, for back in 1951 I brought this to the attention of the National Science Foundation.

What is not realized today is that our present scientific potential can be measured quite accurately by a survey of the grades 4, 5, 6 and 7, or translated ages 9 to 12 or 13 (mostly preteen age levels) where our future engineers and scientists are born.

It is not enough to point out the drastic lack of scientific talent. High schools, colleges and universities must join hands with the elementary schools to create a technical revolution in elementary school teaching, particularly of arithmetic.

What we have refused to accept is the fact that the trouble with book learning has been *too much books* and not enough laboratory aids and devices to make educational work interesting.

Divide the problem into two basic steps:

(1) Elementary schools where it is possible to initiate a new approach to science, and

(2) High school, college and university, where we can use emergency methods to help repair the damage of poor teaching methods of the past in elementary schools.

We are therefore (using age 13) at least 7 or 8 years minimum behind the need and that is an optimistic calculation. The facts are more ominous.

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'Insight On Production'

I find that most of your articles are informative and interesting reading. They give me a well-rounded insight on the production field both in the United States and overseas.

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Humble Lectures

The 1955-56 series marks the tenth anniversary for "Humble Lectures in Science." Humble Oil & Refining Company initiated this program at its Baytown, Texas, refinery 10 years ago to provide additional fundamental training to help its technical personnel keep abreast of current developments in science. An average of five courses per year have been offered, entirely at company expense; 46 have been given by 36 professors, each eminent in his field of endeavor. They have come from 23 universities in the U. S., Holland, England, and Canada.

Participation in a course is entirely voluntary, selection being made from among those who have indicated interest in the specific subject. The program has proved very popular with the staff; each year between 70 and 80 have participated. It has provided each technical employee an opportunity to take a course in which he is interested about every two years.

The current series was initiated late in July with a course in operations research taught by Professor George E. Kimball of the chemistry department at Columbia University. In September Professor Robert B. Watson of the physics department at The University of Texas will present lectures on electronic circuits. For his third participation, Professor R. C. Fuson of the chemistry department at University of Illinois, will teach a course in organic chemistry in December.

The last two courses will be taught in June, 1956.